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The Science Series

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CLIMATE

Climate

Considered Especially in Relation to Man

By

Robert DeCourcy Ward

Assistant Professor of Climatology in Harvard University

Illustrated

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PREFACE

THE preparation of a volume on *Climate* for The Science Series was suggested to me by the Editors in October, 1904. I was asked to prepare a book " which can be read by an intelligent person who has not had special or extended training in the technicalities of the science, . . . the book to be such as would not compete with strictly meteorological text-books, but to handle the broad questions of climate." It so happened that it was then already in my mind to prepare a book dealing with certain large relations of climate, which might serve as supplementary reading for the students in my course on General Climatology in Harvard University. The present volume is an attempt on my part to write a book which shall meet the wishes of the Editors of The Science Series and at the same time fit the needs of my students.

Climate is based on lecture-notes which have been accumulating for the past ten years. It does not attempt to present any very new or original material, but it does aim to co-ordinate and to set forth clearly and systematically the broader facts of climate in such a way that, as desired by the Editors, the general reader, although not trained " in the technicalities of the science," may find it easy to appreciate

them. At the same time, the needs of the teacher and student have been kept constantly in mind, and the subject-matter has been arranged in such a way as seems best to adapt it for purposes of thorough study.

Climate may be considered in a way as supplementing the first volume of Dr. Julius Hann's *Handbuch der Klimatologie*, an English translation of which was prepared by me and published in 1903. In that book, the standard work of its kind in the world, the principles of climatology are clearly set forth. My present volume deals with matters which are either omitted altogether in the *Handbook*, or else are very briefly treated therein. *Climate* is wholly independent of Hann's splendid work, except in so far as my study of that book inspired me to prepare this one.

The general scope and purpose of the different sections in *Climate* are as follows. The Introduction is essentially a very condensed synopsis of the first six chapters of Hann's first volume, with the addition of some other matter. Chapter I gives a sketch of the classification of the zones. Chapters II and III give a brief summary of the general climatic types which result from the control of land and water, and of altitude, over the more important elements of climate. Chapters IV, V, and VI are intended to give an outline of the climatic characteristics of the zones in a simple and vivid form, with the least possible use of tabular matter. For further general information on this subject, reference may be made to

the world-charts of temperature, winds, cloudiness, rainfall, etc., given with greater or less completeness in the various text-books of meteorology, and, very fully, in the *Atlas of Meteorology*. In Chapter VII the attempt is made to give a survey of some of the relations between weather and climate and a few of the more important diseases. Little information on this subject is readily accessible to the general reader. The life of man in the tropics, the temperate zones, and the polar zones is considered in Chapters VIII to X. No attempt has been made to discuss this subject in detail, for to do so would far exceed the limits set for this book. It has rather been my plan to pick out typical illustrations here and there, as suggestions. Many of the cases referred to will probably be familiar to teachers and students of geography, but the co-ordination of all the examples by climatic zones and by the natural climatic subdivisions of these zones will, it is hoped, tend to give adequate emphasis to the climatic factor, which has hitherto been much neglected. The final chapter, on changes of climate, deals with historic and periodic, and not with geologic changes. The last phase of the subject has been fully discussed in many books, while the former, which are of more interest to most persons, have received much less attention. The question of the influence of forests on climate, which many readers may expect to find considered in this book, is omitted because it is adequately taken up in Hann's *Handbook* (Vol. I).

I have drawn very freely upon Hann's *Handbuch der Klimatologie,* Vols. II and III (2d ed., Stuttgart, 1897), as well as upon his *Lehrbuch der Meteorologie* (2d ed., Leipzig, 1906), two books which are so complete in all details that every writer on meteorological or climatological subjects is inevitably very dependent upon them. The curves in Chapters IV, V, and VI were all drawn from data given in the *Lehrbuch.* In the chapters on the life of man in the different zones, I have made liberal use of Ratzel's *Anthropogeographie* (2d ed., Stuttgart, 1899). The principal references other than these are the following: W. M. Davis: *Elementary Meteorology* (Boston, 1902); A. J. and F. D. Herbertson: *Man and His Work* (London, 1899); W. Köppen: *Klimakunde. I. Allgemeine Klimalehre* (2d ed., Leipzig, 1906); A. Supan: *Grundzüge der physischen Erdkunde* (3d ed., Leipzig, 1903); W. Trabert: *Meteorologie und Klimatologie* (Leipzig and Vienna, 1905); W. J. van Bebber: *Hygienische Meteorologie* (Stuttgart, 1895); A. Woeikof: *Die Klimate der Erde* (Jena, 1887); *Atlas of Meteorology* (Edinburgh, 1899).

I am indebted to the publishers, Messrs. G. P. Putnam's Sons, for their generous permission to me to use certain parts of this book in an article prepared for the *Encyclopædia Britannica* in 1906, as well as for the privilege which they willingly accorded me of publishing as separate articles many of the chapters included in this book. Chapters I to III have appeared in the *Bulletin of the American*

Geographical Society; Chapters IV to VI in the *Journal of Geography;* Chapter VII in the *Bulletin of the Geographical Society* of Philadelphia, and Chapter XI in the *Popular Science Monthly.* My thanks are also due to my fellow-workers, Professors Hann, Mohn, Supan, Köppen, Angot, and W. M. Davis, and also to Dr. Fridtjof Nansen, for permission to reproduce some of their maps and diagrams in the present volume. Mr. Henry S. Mackintosh, of Keene, N. H., has very kindly helped me in the proof-reading.

ROBERT DE C. WARD.

Harvard University,
Cambridge, Mass.,
December, 1907.

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CLIMATE

INTRODUCTION

Meaning and Scope of Climatology—Relation of Meteorology and Climatology—Literature of Climatology—The Climatic Elements and their Treatment—Solar Climate—Physical Climate.

Meaning and Scope of Climatology. The word *klima* (from *κλίνειν,* to incline), as used by the Greeks, originally referred to the supposed slope of the earth toward the pole, or to the inclination of the earth's axis or of the sun's rays. It may, perhaps, have had reference to the different exposures of mountain slopes. Later, probably after Aristotle's time, it came to be used as about equivalent to our *zone,* but at first it was simply a mathematical or an astronomical term, not associated with any idea of physical climate. A change of latitude in those days meant a change of *climate.* Such a change was gradually seen to mean a change of atmospheric conditions as well as a change in length of day. Thus *klima* came to have its present meaning.

An excellent illustration of the ancient meaning of

the word *klima* is found in the system of climates pro posed by the famous geographer, Ptolemy. This was a division of the earth's surface between equator and north pole into a series of climates, or parallel zones, separated by latitude circles and differing from one another simply in the length of their longest day. Ptolemy's subdivision of the earth's surface was really nothing but an astronomical climatic table.

Climate, as we use the term, is the resultant of the average atmospheric conditions, or, more simply, it is the average condition of the atmosphere. *Weather* is a single occurrence, or event, in the series of conditions which make up the *climate.* The *climate* of a place is in a sense its average weather. The average values of these atmospheric conditions can be determined only by means of careful observations, continued for a period sufficiently long to give accurate results. Climatology is the study or science of climates.

Relation of Meteorology and Climatology. Meteorology and climatology are interdependent. It is impossible to distinguish very sharply between them. Each needs the results obtained by the other. In a strict sense, meteorology deals with the physics of the atmosphere. It considers the various atmospheric phenomena individually, and seeks to determine their physical causes and relations. Its view is largely theoretical. The aspect of meteorology which is of most immediate practical importance to man is that which concerns weather-forecasting.

When the term meteorology is used in its broadest meaning, climatology is a subdivision of meteorology. Climatology is largely descriptive. It aims to give as clear a picture as possible of the interaction of the various atmospheric phenomena at any place on the earth's surface. It rests upon physics and geography, the latter being a very prominent factor. Climatology may almost be defined as geographical meteorology. Its main object is to be of practical service to man. Its method of treatment lays most emphasis on the elements which are of the most importance to life. Climate and crops, climate and industry, climate and health, are subjects of vital interest to man. No other science concerns man more closely in his daily life.

Literature of Climatology. Scientific climatology is based upon numerical results obtained by systematic, long-continued, and accurate meteorological observations. The essential part of its literature is therefore found in the collections of data published by the various meteorological services and observatories. In addition, large numbers of short sketches and notes on climate, partly the more or less haphazard accounts of travellers, partly the more careful studies of scientific observers, are scattered through a wide range of geographical and other publications. The only comprehensive text-book of climatology is the *Handbuch der Klimatologie* of Professor Julius Hann, of the University of Vienna. This is the standard book on the subject, and upon it is based

much of the present volume, and of other recent discussions of climate. The second edition of this work, in three volumes, was published in 1897 (Stuttgart, Engelhorn). The first volume deals with general climatology, and has been translated into English.[1] The second and third volumes are devoted to the climates of the different countries of the world. Woeikof's *Die Klimate der Erde* (Jena, Costenoble, 1887) is also a valuable reference book. The first part concerns general relations of climate, particularly to rivers and lakes, to vegetation, and to snow-cover, while the second part deals with the climates of special areas. The standard meteorological journal of the world, the *Meteorologische Zeitschrift* (Braunschweig, Vieweg, monthly), is indispensable to anyone who wishes to keep in touch with the latest publications on climatology, for it contains the most complete record of such literature, as well as a large number of original notes and discussions. The newest and most complete collection of charts is that in the *Atlas of Meteorology* (London, Constable, 1899), in which also there is an excellent bibliography. For the titles of more recent publications reference may be made to the *International Catalogue of Scientific Literature* (annual volume on *Meteorology*); or to the more frequent bibliographical lists in the *Meteorologische Zeitschrift;* the *Monthly Weather Review* (Washington, U. S. Weather Bureau); the *Quarterly Journal of*

[1] By R. De C. Ward. London and New York, Macmillan, 1903.

the Royal Meteorological Society (London), and the *Halbmonatliches Litteraturverzeichniss der "Fortschritte der Physik"* (Braunschweig, Vieweg, twice a month).

The Climatic Elements and their Treatment. Climatology has to deal with the same groups of atmospheric conditions as those with which meteorology is concerned, viz.: temperature (including radiation); moisture (including humidity, precipitation, and cloudiness); wind (including storms); pressure; evaporation, and also, but of less importance, the composition and the chemical, optical, and electrical phenomena of the atmosphere. The characteristics of each of these so-called *climatic elements* are set forth in a standard series of numerical values, based on careful, systematic, and long-continued meteorological records, corrected and compared by well-known methods. Various forms of graphic presentation, by curves, or by wind roses, etc., are employed to emphasise and simplify the numerical results. Instructions concerning the use, exposure, hours of observation, and corrections of the ordinary meteorological instruments; as well as for obtaining the usual numerical results, are published by the various governmental meteorological services. In Hann's *Handbook of Climatology,* Vol. I, will be found a general discussion of the methods of presenting the different climatic elements, and of the reasons for adopting the accepted scheme of presentation. The most complete guide in the numerical, mathematical,

and graphic treatment of meteorological data for climatological purposes is Hugo Meyer's *Anleitung zur Bearbeitung meteorologischer Beobachtungen für die Klimatologie* (Berlin, Springer, 1891).

Climate deals first of all with *average* conditions, as is apparent from the definition given above. But *means* may be made up of very different values of the elements which go into them, and therefore a satisfactory presentation of a climate must include more than mere averages. It must take account, also, of regular and irregular daily, monthly, and annual changes, and of the departures, mean and extreme, from the average conditions which may occur at the same place in the course of time. The mean minimum and the mean maximum temperature or rainfall of a month, or a season, are important data, not in any way replaced by a knowledge of the mean monthly or seasonal temperature and rainfall. Further, a determination of the frequency of occurrence of a given condition, or of certain values of that condition, is important, for periods of a day, month, or year, as, for example, the frequency of winds according to direction or velocity; or of different amounts of cloudiness; or of temperature changes of 5, or 10, or more degrees; the number of days with and without rain or snow in any month, or year, or with rain of a certain amount, etc. The probability of occurrence of any condition, as of rain in a certain month; or of a temperature of 32°, for example, is also a useful thing to know concerning a climate. In the

past, climatology has been too much concerned with monthly, seasonal, and annual averages. An important addition to the usual climatic summaries would be the introduction, for all regions in which the cyclonic or storm control of weather conditions is characteristic, of the cyclonic unit, so that, for example, the average duration and value of cyclonic ranges of temperature in the several months, or the proportion of the annual rain and snowfall received from cyclonic storms and from local thunderstorms, might be determined.[1]

Solar Climate. The sun is clearly the principal control of climates on the earth's surface. The general distribution of temperature, as well as the seasonal and diurnal changes, all depend upon changes in the intensity of sunshine. Hence a brief consideration of the distribution of insolation over the earth's surface is essential to a proper understanding of climates. Climate, in so far as it is controlled solely by the amount of solar radiation which any place receives by reason of its latitude, is called *solar climate.* Clearly, all places on the same latitude circle would have the same solar climate, for the intensity and amount of insolation depend upon the angle of incidence of the sun's rays, and upon the length of day, and both of these depend upon latitude. Solar climate alone would prevail if the earth had a homo-

[1] See R. DeC. Ward: *Suggestions Concerning a More Rational Treatment of Climatology.* Report Eighth International Geographic Congress, Washington, D. C., 1904, pp. 277-293.

geneous land surface, and if there were no atmosphere. For under these conditions, and without air or ocean currents, the distribution of temperature at any place would depend solely on the amount of energy received from the sun, and upon the loss of heat by radiation. And these two factors would have the same value at all points on the same latitude circle.

The relative amounts of insolation received at different latitudes and at different times have been carefully determined. The values all refer to conditions at the upper limit of the earth's atmosphere, *i. e.*,

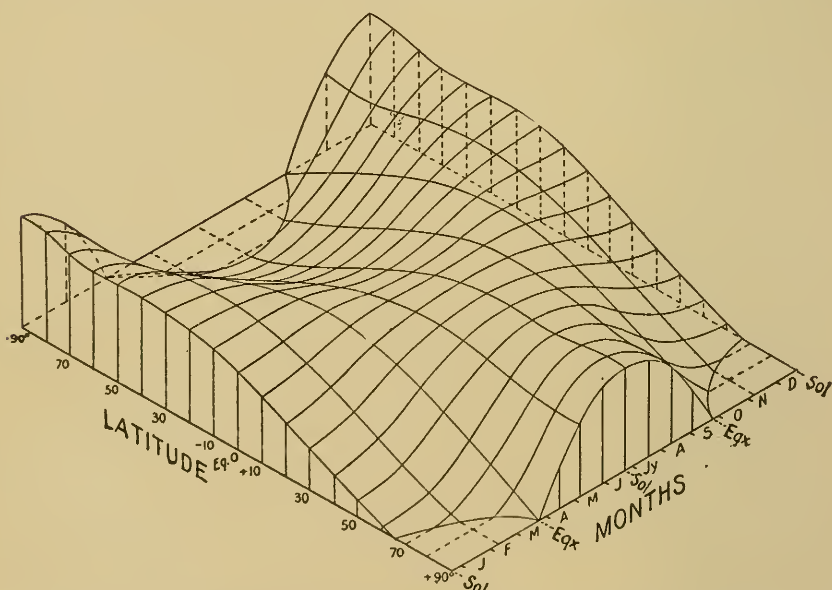

FIG. I. DISTRIBUTION OF INSOLATION OVER THE EARTH

without the effect of absorption by the atmosphere. The accompanying diagram (see Fig. I) shows very clearly the distribution of insolation in both hemi-

spheres at different latitudes and at different times in the year. The latitudes are given at the left margin and the time of year at the right margin. The values of insolation are shown by the vertical distance above the plane of the two margins.

At the equator, where the day is always twelve hours long, there are two maxima of insolation at the equinoxes, when the sun is vertical at noon, and two minima at the solstices, when the sun is farthest off the equator. The annual curves show that the values do not vary much through the year, because the sun is never very far from the zenith, and day and night are always equal. There is a slight difference in the insolation at the two maxima, owing to a difference in the sun's distance, the earth's orbit being an ellipse and not a circle. The earth is nearer the sun in the winter of the northern hemisphere, and therefore the spring maximum is somewhat greater than the autumn maximum. The varying distance from the sun also explains the fact that the maxima of insolation do not come exactly on the dates of the equinoxes.

These conditions are clearly brought out in curve 1 of Fig. 2, which shows the annual march of insolation on the equator. The law of the distribution of insolation would be simple if the sun were always on the equator, for the angle of insolation and the length of day and night would then always remain the same. But under existing conditions, both the angle of insolation and the length of day are constantly changing, and the interaction between these two controls

becomes very complex. As the latitude increases, the angle of insolation becomes more oblique, and the intensity of insolation decreases, but at the same time the length of day rapidly increases during the summer, and towards the pole of the hemisphere which is having its summer the gain in insolation from the

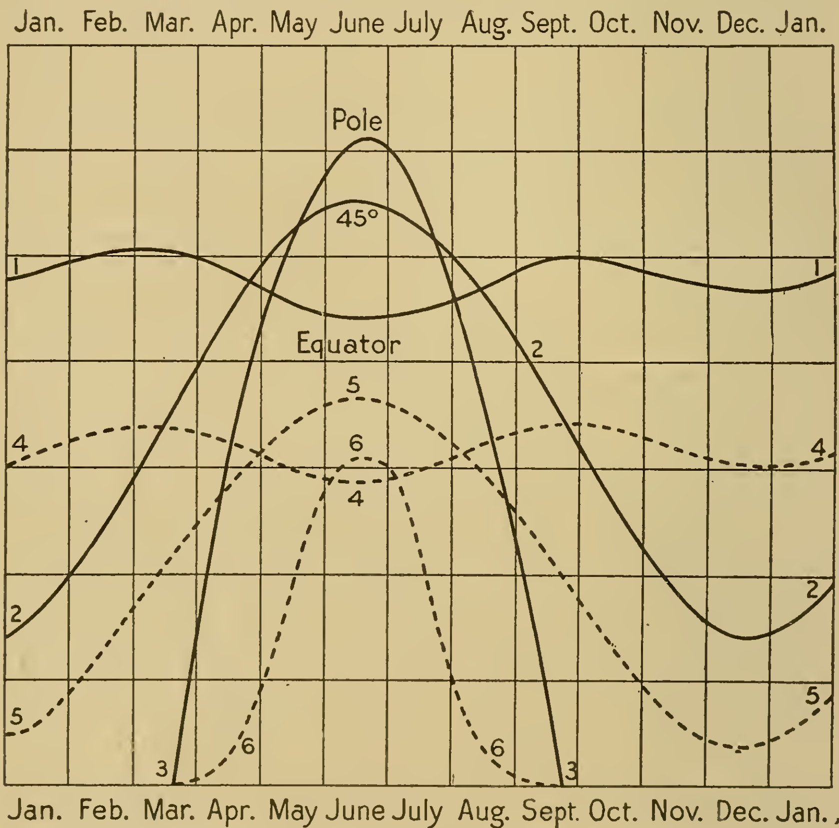

FIG. 2. ANNUAL VARIATION OF INSOLATION AT DIFFERENT LATITUDES

latter cause more than compensates for the loss by the former. The double period of insolation, above noted for the equator, prevails as far as about lat. 12° N. and S.; at lat. 15° the two maxima have united,

and the same is true of the minima. Take the case of an intermediate latitude, like 45° N. (see curve 2, Fig. 2). Here there is one minimum, in December, when the sun is south of the equator, and one maximum, in June, when the sun is north. The slight displacement of this maximum and minimum from the exact date of the two solstices is due to the difference in the sun's distance. At the north pole (curve 3, Fig. 2), there is one maximum at the summer solstice, and no insolation at all while the sun is below the horizon. The distribution of insolation at different latitudes on the same day is also interesting. On June 21, for example (see Fig. 1), the equator has a day twelve hours long, but the sun's maximum altitude is only 66½°, *i. e.,* it does not reach the zenith, and the amount of insolation is less than at the equinox. On the northern tropic, however, the sun is vertical at noon, and the day is between thirteen and fourteen hours long. Hence the amount of insolation received at this latitude on June 21 is greater than that received on the equinox at the equator. As one passes from the tropic to the pole the sun stands lower and lower at noon, and the value of insolation would steadily decrease with latitude if it were not for the increase in the length of day. Going polewards from the northern tropic on June 21, the value of insolation increases for a time, because, although the sun is lower, the number of hours during which it shines is greater. A maximum value is

reached at about lat. 43½° N. The decreasing altitude of the sun then more than compensates for the increasing length of day, and the value of insolation diminishes, a minimum being reached at about lat. 62°. Then the rapidly increasing length of day towards the pole (the day being twenty-four hours long beyond the Arctic circle) again brings about an increase in the value of insolation, until a maximum is reached at the pole which is greater than the value received at the equator at any time. (See Fig. 2, in which the curves are all drawn on the same scale). The length of day is the same on the Arctic circle as at the pole itself, but while the altitude of the sun varies during the day on the former, being at the horizon at midnight and highest at noon, the altitude at the pole remains 23½° throughout the twenty-four hours. The result is to give the pole a maximum (See Fig. 3, curve marked 1.00.). On June 21, there are therefore two maxima of insolation, one at lat. 43½° and one at the north pole. From lat. 43½° N., insolation decreases to zero on the Antarctic circle, for sunshine falls more and more obliquely, and the day becomes shorter and shorter. Beyond lat. 66½° S. the night lasts twenty-four hours. On December 21 (see Fig. 1), the conditions in southern latitudes are similar to those in the northern hemisphere on June 21, but the southern latitudes have higher values of insolation because the earth is then nearer the sun.

At the equinox, the days are equal everywhere, but

the noon sun is lower and lower with increasing latitude in both hemispheres until the rays are tangent to the earth's surface at the poles (except for the effect of refraction). Therefore, the values of insolation diminish from a maximum at the equator to a minimum at both poles. From the fact that the southern hemisphere has its summer in perihelion and its winter in aphelion, it follows that there is a greater difference between the seasonal values of insolation south of the equator than north of it. In other words, the solar climate of the southern hemisphere is more severe than that of the northern. Nevertheless, owing to the fact that the earth moves more rapidly around its orbit when nearest the sun, both hemispheres receive equal amounts of insolation at the same latitudes, and in the mean of the year, both have the same amount of insolation.

The values of insolation thus far considered have reference to the upper limit of the earth's atmosphere, or to the earth's surface assuming that no atmosphere exists. The effect of the atmosphere is to weaken the sun's rays. The more nearly vertical the sun, the less the thickness of atmosphere traversed by the rays. The values of insolation at the earth's surface, after passage through the atmosphere, have been calculated. They vary much with the condition of the air, as to dust, clouds, water vapour, etc. In Fig. 2, the broken lines, 4, 5, and 6, show the values of insolation at the equator, lat. 45° N., and the north pole, allowing for a loss of 25% during the passage through the

atmosphere, *i. e.*, with a coefficient of transmission 0.75. This is higher than that usually observed, even under very favourable conditions, with the sun in the zenith. As a rule, even when the sky is clear, about one-half of the solar radiation is lost during the day

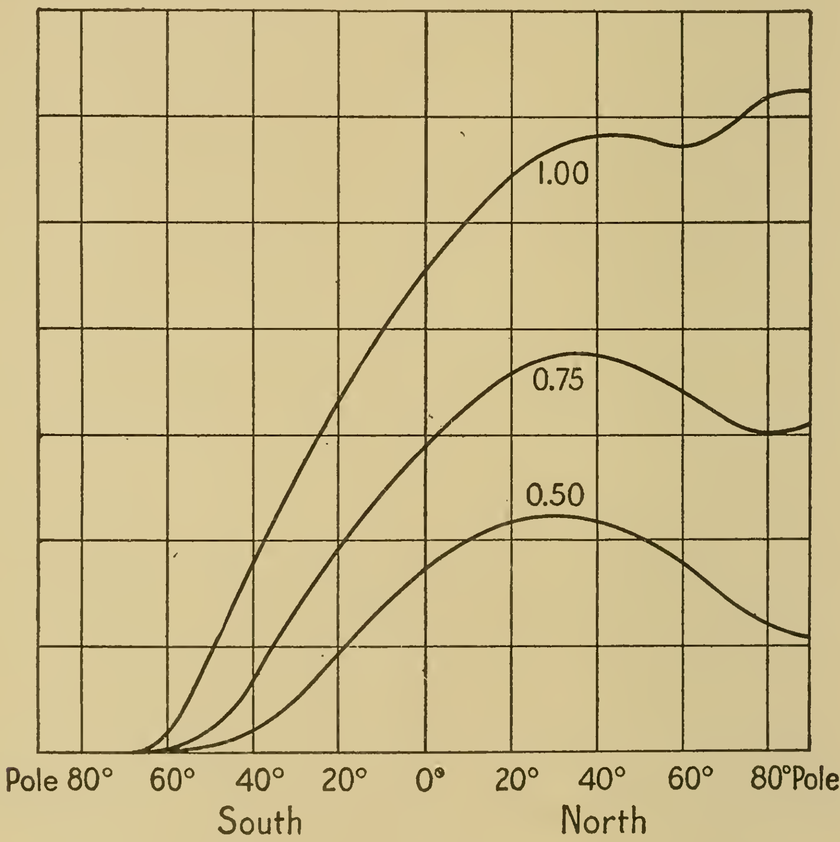

Fig. 3. Insolation Received at Different Latitudes on June 21

by atmospheric absorption. The great weakening of insolation at the pole, where the sun is very low, is especially noticeable. The effect of the atmosphere is also shown in Fig. 3. The upper curve represents

the total quantity of insolation received at the earth's surface with a coefficient of transmission of 1.00 (*i. e.,* no loss). Under such conditions, as already noted, there are two maxima on June 21, at lat. 43½° N. and at the north pole. The second curve corresponds to a coefficient of transmission of 0.75, which is also used in the broken curves of Fig. 2. Under these conditions, there is but one maximum, at about lat. 36° N., and the north pole has only 49% of the total radiation emitted by the sun. The third curve is based on a coefficient of transmission of 0.50, and shows one maximum at lat. 32° N., the pole receiving only 18% of the total amount which reaches the upper limit of the atmosphere at that point. The curves 0.75 and 0.50 show that, taking the atmosphere into account, even in midsummer the amount of insolation decreases from between lats. 30° and 40° to the pole. The following table (after Angot) shows the effect of the earth's atmosphere (coefficient of transmission 0.7) upon the value of insolation received at sea level.

VALUES OF DAILY INSOLATION AT THE UPPER LIMIT OF THE EARTH'S ATMOSPHERE AND AT SEA LEVEL.

Lat.	Upper limit of atmosphere			Earth's surface		
	Equator	40°	N. Pole	Equator	40°	N. Pole
Winter Solstice .	948	360	0	552	124	0
Equinoxes . .	1000	773	0	612	411	0
Summer Solstice .	888	1115	1210	517	660	494

The following table gives, according to Zenker, the relative thickness of the atmosphere at different altitudes of the sun, and also the amount of transmitted insolation.

RELATIVE DISTANCES TRAVERSED BY SOLAR RAYS THROUGH THE ATMOSPHERE, AND INTENSITIES OF RADIATION PER UNIT AREAS

Altitude of Sun.										
0°	5°	10°	20°	30°	40°	50°	60°	70°	80°	90°
Relative Lengths of Path through the Atmosphere.										
44.7	10.8	5.7	2.92	2.00	1.56	1.31	1.15	1.06	1.02	1.00
Intensity of Radiation on a Surface Normal to the Rays.										
0.0	0.15	0.31	0.51	0.62	0.68	0.72	0.75	0.76	0.77	0.78
Intensity of Radiation on a Horizontal Surface.										
0.0	0.01	0.05	0.17	0.31	0.44	0.55	0.65	0.72	0.76	0.78

Physical Climate. It is clear that the distribution of insolation, just considered, explains many of the large facts of the distribution of temperature—for example, the decrease of temperature from equator to poles; the double maximum of temperature on and near the equator; the increasing seasonal contrasts with increasing latitude, etc. But it is equally apparent that the distribution of temperature often does not follow the distribution of insolation closely, for, if it did so, the two poles would be warm at the times of their respective maxima of insolation. The high values of *insolation* at the poles do not correspond to high temperatures, as will be seen in a later chapter (VI).

The old view which thus explained an "open polar sea" was erroneous. The distribution of insolation suggests a subdivision of the earth's surface into three distinct belts. In one, within about 12° of the equator, there are two maxima and two minima. In a second, there is one maximum; and for part of the year the absence of the sun reduces the amount to zero. In a third, the conditions are intermediate; there is one maximum and one minimum, but there is no time when the value of insolation decreases to zero. Of the second and third of these belts, there are two divisions, one in the northern and one in the southern hemisphere. It will be noted that the tropics, the polar, and the temperate zones roughly correspond to these insolation belts.

The regular distribution of solar climate between equator and poles which would exist on a homogeneous earth, whereby similar conditions prevail along each latitude circle, is very much modified by the unequal distribution of land and water; by differences of altitude; by air and ocean currents; by varying conditions of cloudiness, and so on. Hence the climates met with along the same latitude circle are no longer all alike. Solar climate is greatly modified by atmospheric conditions and by the surface features of the earth, and what is known as *physical climate* is the result. The uniform latitudinal arrangement of solar climatic belts is interfered with. Physical climate results from the reaction of the earth's surface features upon the atmosphere. According to the

dominant control, in each case, we have solar, continental, marine, and mountain climates. In the first named, latitude is the essential; in the second and third, the effect of land or water; in the fourth, the effect of altitude.

CHAPTER I

THE CLIMATIC ZONES AND THEIR SUBDIVISIONS

Classification by Latitude Circles: The Five Classic Zones; *Klima* as Used by the Greeks; Ptolemy's Climates; Parmenides; Polybius; Posidonius; Aristotle; Eudoxus; Strabo; Hippocrates—Temperature Zones: Supan; Köppen; Gebelin—Wind Zones: Davis; Woeikof—Summary and Conclusions—Necessary Subdivisions of the Zones.

Classification by Latitude Circles. So great is the variety of climates to be found in different parts of the world that it has long been customary to classify these climates roughly into certain broad belts. These are the climatic zones. A simple grouping of this kind can, however, obviously take account only of the most general characteristics of the climates which are included within each zone. The five zones with which we are most familiar are the so-called torrid, the two temperate, and the two frigid zones. The torrid, or, better, the tropical zone, naming it by its boundaries, is limited on the north and south by the two tropics of Cancer and Capricorn, the equator dividing the zone into two equal parts. The temperate zones are limited towards the equator by the tropics, and towards the poles by the Arctic and Antarctic circles. The two frigid, or, better, the two polar

zones, are caps covering both polar regions, and bounded on the side towards the equator by the Arctic and Antarctic circles.

These five zones are classified on purely astronomical or mathematical grounds. They are really zones of sunshine, or of solar climate. Within the tropical zone, the sun reaches the zenith at two different times in the year; its greatest possible zenith distance is 47°; the day is never less than ten and a half hours long. On the tropics themselves, the sun reaches the zenith but once a year. In the polar zones, the sun is below the horizon for twenty-four hours at least once in winter, and is above the horizon for the same length of time at least once in summer. On the polar circles, the noon altitude of the sun decreases to 0° on the shortest day. The temperate zone has conditions between these two extremes. At no point can the sun be in the zenith; nor, except on the polar circles, is there ever anywhere a twenty-four-hour day or night.

The tropical zone has the least annual variation of insolation. It has the maximum annual amount of insolation. Its annual range of temperature is very slight. It is the summer zone. Beyond the tropics the contrasts between the seasons rapidly become more marked. The polar zones have the greatest variation in insolation between summer and winter. They also have the minimum amount of insolation for the whole year. They may well be called the winter zones, for their summer is so short and cool that the heat is insufficient for most forms of vegeta-

tion, especially for trees. The temperate zones are intermediate between the tropical and the polar in the matter of annual amount and of annual variation of insolation. Temperate conditions do not characterise these zones as a whole. They are rather the seasonal belts of the world. These five zones further differ more or less from one another in the character of their animals and plants, and in the conditions of human life within their boundaries.

Taking the area of a hemisphere as unity, the relative areas of these zones are as follows:

Tropical	0.40
Temperate	0.52
Polar	0.08

This subdivision of the earth's surface on the basis of the geometrical distribution of sunshine dates from the time of the early Greek philosophers and geographers, but it is impossible to determine with certainty just when and by whom the various suggestions in this connection were made. The famous geographer Ptolemy, who lived in the second century A.D., used different schemes at different times. In the lower latitudes the breadth of a *klima,* or zone, was fixed by the difference of a quarter of an hour in the length of the longest day, but in higher latitudes differences of half an hour, an hour, and finally a month were the determining factors.

Parmenides, who flourished about the middle of the fifth century B. C., proposed a five-zone division of the earth's surface not very unlike our present sys-

tem. These zones were a torrid zone, uninhabitable because of heat; two frigid zones, uninhabitable because of cold; and two intermediate zones, of moderate temperature, suitable for man. The exact limits assigned to these zones are not known with certainty; but it is reasonable to suppose that the Arctic circle was even then recognised as a natural boundary for the north polar zone, and it is pretty clear that the temperate zone was much smaller, and the torrid zone much larger, than in our present classification. (See Fig. 4.)

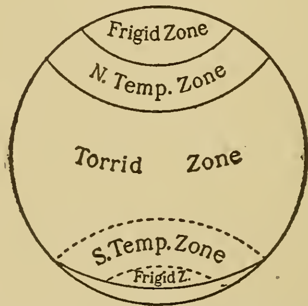

FIG. 4. THE ZONES IN THE TIME OF PARMENIDES

The exact boundaries of the different zones varied more or less for some time, as astronomical knowledge became more and more exact, and as the habitable area of the earth's surface was gradually extended, but the scheme was generally adopted by later writers. Polybius (born about B.C. 204), however, divided his torrid zone into two parts by the equator, and Posidonius (born about B.C. 135) divided his torrid zone into three parts, making six and seven zones respectively. Aristotle (born B.C. 384)

limited the torrid zone by the tropics, and the north temperate zone by the Arctic circle; but there is doubt whether he really meant the fixed Arctic circle which we know. He believed both temperate zones habitable, thus limiting the uninhabitable area to the astronomical tropical zone. Eudoxus, of Cnidus, who lived about B.C. 366, used a division of a quadrant of the earth's circumference into fifteen parts, of which four belonged to the torrid, five to the temperate, and six to the frigid zone. The tropics were thus fixed at latitude 24°. Strabo (born about B.C. 54), opposed the prevailing view that the whole of the belt between the two tropics was uninhabitable, and also first clearly set forth the opinion that the temperature decreases with increasing altitude above sea-level, as well as with increasing latitude. Strabo also had some fairly distinct ideas regarding local differences of climate resulting from the influence of land and water and of mountain barriers, and noted several effects of climate upon man and upon vegetation. He appreciated the fact that the zones were zones of temperature as well as zones of sunshine. As early as about 400 B.C., Hippocrates had endeavoured to show a causal relation between sunshine and the topography of a district on the one hand and the characteristics of its inhabitants on the other. He also gave an outline of geographical pathology.[1]

[1] The older views regarding the climates and the habitability of the five zones were thus stated by Virgil (*Georgics*, i, 233-239, translation by Davidson): "Five zones embrace the heavens;

Temperature Zones. The classification of the climatic zones on the basis of the geometrical distribution of sunshine serves very well for purposes of simple description, but a glance at any isothermal chart shows at once that the isotherms do not coincide with the latitude lines. In fact, in the higher latitudes, the former often follow the meridians more closely than they do the parallels of latitude. The astronomical zones—*i. e.,* the zones of light—therefore differ a good deal from the zones of heat. Hence it has naturally been suggested that the zones be limited by isotherms rather than by parallels of latitude, and that a closer approach be thus made to the actual conditions of climate.

Supan (see Fig. 5) has suggested limiting the hot belt, which corresponds to the old torrid zone, but is slightly greater, by the two mean annual isotherms of 68°—a temperature which approximately coincides with the polar limit of the trade winds and with the polar limit of palms. The latter is considered by Grisebach to be the truest expression of a tropical climate. The hot belt widens somewhat over the continents, chiefly because of the mobility of the ocean waters, whereby there is a tendency towards an equalisation of the temperature between equator

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whereof one is ever glowing with the bright sun, and scorched forever by his fire; round which the two farthest ones to the right and left are extended, stiff with cerulean ice and horrid showers. Between these and the middle zones, two by the bounty of the gods are given to weak mortals; and a path is cut through both, where the series of the signs might revolve obliquely."

and poles in the oceans, while the stable lands acquire a temperature suitable to their own latitude. Furthermore, the unsymmetrical distribution of land in the low latitudes of the northern and southern hemispheres results in an unsymmetrical position of the hot belt with reference to the equator, the belt extending

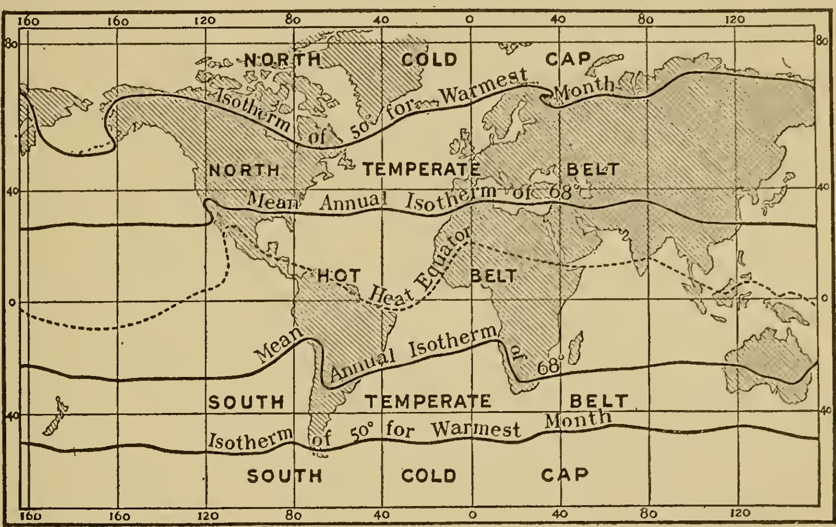

FIG. 5. SUPAN'S TEMPERATURE ZONES

farther north than south of the equator. The polar limits of the temperate zones are fixed by the isotherm of 50° for the warmest month. This is a much more satisfactory limit than the mean annual isotherm of 32°, which has also been suggested; for climates differing very widely from one another are found to have the same mean annual temperature of 32°. The latter value has chiefly a theoretical interest, but is of some practical importance in its relation to the regions of frozen ground. Summer heat is more im-

portant for vegetation than winter cold; and where the warmest month has a temperature below 50°, cereals and forest trees do not grow, and man has to adjust himself to the conditions in a very special way. The two polar caps are not symmetrical as regards the latitudes which they occupy. The presence of extended land masses in the high northern latitudes carries the temperature of 50° in the warmest month farther poleward there than is the case in the corresponding latitudes occupied by the oceans of the southern hemisphere, which warm less easily and are constantly in motion. Hence the southern cold cap, which has its equatorial limits at about lat. 50° S., is of much greater extent than the northern polar cap. So far as this south polar zone is concerned, the presence or absence of an Antarctic continent is immaterial; for such a land mass must be ice-covered, and hence cannot operate to raise the temperature as in the case of a land surface to which the sun's rays have immediate access. The northern temperate belt, in which the great land areas lie, is much broader than the southern, especially over the continents. These temperature zones have real significance. They emphasise the natural conditions of climate more than can be the case in any subdivision by latitude circles, and they bear a fairly close resemblance to the old zonal classification of the Greeks.

In high latitudes, neither the mean annual temperature nor the temperature of the coldest month is nearly as important a climatic control over vegetation

Fig. 6. Temperature Zones after Köppen

as is the temperature of summer, from the point of view of climate as a whole, and especially in relation to organic life. The summer temperatures determine habitability, the limits of plant growth, and the general conditions of human life. Hence, in the higher latitudes, zones bounded by mean annual isotherms are no great improvement over zones limited by latitude circles.

Another classification of temperature zones has been suggested by Köppen (see Fig. 6). In this, the length of time during which the temperature remains within certain fixed limits, these limits having well-marked relations to organic life, is taken into account. Two critical daily mean temperatures, 68° and 50°, and the duration of these temperatures for periods of one, four, and twelve months, are the factors in this classification. These temperatures are not reduced to sea-level. A normal duration of a temperature of 50° for less than a month fixes very well the polar limit of trees and the limits of agriculture. Near this line are found the last groups of trees in the tundras. A temperature of 50° for four months marks the limit of the oak, and also closely coincides with the limits of wheat cultivation. North of the tree limit, agriculture ceases, and man's food is to be sought very largely in the sea. With the approach to this line, the period of plant growth is shortened more and more, agricultural operations become restricted, and occupations of other kinds are followed. These critical temperatures and their

varying periods of duration from the basis of the following classification:

1. Tropical belt: all months *hot* (over 68°). This is almost altogether within the tropics; it reaches, in round numbers, from latitude 20° N. to 16 S.

2. Sub-tropical belts: 4 to 11 months hot (over 68°); 1 to 8 months *temperate* (50°–68°.)

3. Temperate belts: 4 to 12 months temperate.

4. Cold belts: 1 to 4 months temperate; the rest *cold* (below 50°).

5. Polar belts: all months cold.

The temperate belts of both hemispheres are further subdivided into three districts [1]—the steadily temperate belt [2] is found only on the oceans; the belt of hot summers [3] only on the continents; and the third, with moderate summers and cold winters,[4] extends around the world, with the exception of a notable interruption over Siberia.

In the second of these subdivisions, except in eastern North America and Asia, the rainfall is generally deficient; irrigation is more or less necessary, and deserts and steppes characterise the continental portions. Only in the monsoon districts of southern and eastern Asia, of Brazil, and of south-eastern North America, do we find high temperatures combined with

[1] All characterised by having at least four months temperate (50°-68°), and not more than four months hot (over 68°).

[2] No month over 68° or below 50°.

[3] Has temperatures below 50° for one or more months.

[4] Has less than four months, but not less than one month, temperate (50°-68°).

high relative humidity. The third subdivision above noted is now the chief seat of human development. Over a large part of the cold belt of the northern hemisphere, the ground is permanently frozen, thawing only a little on the surface in summer. Nevertheless, in portions of it trees and hardy cereals grow. The polar belts are, as a whole, outside the limits of tree growth.

Another suggestion has been made by Gebelin, who has proposed to select, as limits of the temperate zone, certain visible geographical boundaries, in contrast with the ideal climatic limits based upon the distribution of sunshine. On the oceans, the tropical circles serve as acceptable boundaries on the sides towards the equator, but on the continents the desert belts on both sides of the tropics are reasonable limits, although these deserts do not reach the eastern coasts of the continents. For the polar limits of the temperate zone, the tundras are chosen on the continents, and the summer ice-masses on the oceans.

Wind Zones. While a simple classification of the zones on the basis of temperature is an improvement upon any rigid scheme of division by latitude circles, the heat zones emphasise the element of temperature to the exclusion of such important elements as winds and rainfall. So distinctive are the larger climatic features of the great wind belts of the world, that a classification of climates according to wind systems has been suggested by Davis. As the rain belts of the world are closely associated with these wind sys-

tems, a classification of the zones by winds also emphasises the conditions of rainfall. In such a scheme, the torrid, or tropical zone, with its regularity of weather through the year, and the comparative simplicity of its climatic features, is bounded on the north and south by the margins of the trade wind belts, and is therefore larger than the classic torrid zone. This trade wind zone is somewhat wider on the eastern side of the oceans, and properly includes within its limits the equable marine climates of the eastern margins of the ocean basins, even as far north as latitude 30° or 35°.

Most of the eastern coasts of China and of the United States are thus left in the more rigorous and more variable conditions of the north temperate zone. Through the middle of the trade wind zone extends the sub-equatorial belt, with its migrating calms, rains, and monsoons. On the polar margins of the trade wind zone lie the sub-tropical belts, of alternating trades and westerlies. The temperate zones, with the great irregularity of their weather phenomena and their marked seasonal changes, embrace the latitudes of the stormy westerly winds, having on the equatorward margins the sub-tropical belts, and being somewhat narrower than the classic temperate zones. Towards the poles, there is no obvious limit to the temperate zones, for the prevailing westerlies extend beyond the polar circles. These circles may, however, serve fairly well as boundaries, because of their importance from the point of view of insolation. The

polar zones in the wind classification, therefore, remain just as in the older five-zone scheme.

A compromise between the rigid division by latitude circles and the isothermal and wind classifications has been suggested by Woeikof, who objects to limiting the torrid zone by the tropics on the ground that the high temperatures of that zone, as well as its characteristic winds, extend beyond these parallels. Latitude 30° would be a more natural boundary; but as the westerlies, which are characteristic of the temperate zones, prevail there in winter, latitude 25° is chosen as a compromise between 23½° and 30°. The polar zones are bounded by latitude 65°. When bounded by these several limits, the areas of the different zones are as follows:

Tropical Zone	417
Temperate Zones	490
Polar Zones	93
	1000

Summary and Conclusions. Reviewing what has been said regarding the climatic zones, it would seem that, all things considered, a simple division by isotherms, such as that suggested by Supan (1896), is the best for general use. The early division by latitude circles, while it has the merits of great simplicity, and emphasises the all-important element of sunshine, is too arbitrary, and hence does not accord sufficiently well with the facts of actual climate. Nevertheless, we should not discard the classic zones without recog-

nising that they have a real meaning in relation to solar climate. The grouping of the climatic zones according to wind systems has much to recommend it from a meteorological standpoint, but is not quite simple enough for general use. Its adoption involves an understanding of the great wind and calm belts of the world, and of the migration of these belts. The shifting of the boundaries of the torrid zone also brings in an element of uncertainty which is somewhat confusing, although, as a place in the sub-tropical belt really changes its climate with the seasonal change from westerlies to trades, and *vice versa,* it may reasonably be expected to change its zone. In other words, actual climatic conditions are recognised; and in any case, this is a more reasonable plan than to limit the torrid zone by means of the tropics, which arbitrarily cut across the trade wind belts and separate areas which are climatically the same. The temperature zones proposed by Köppen, while useful in special studies of plant distribution, are too detailed for general adoption.

Whatever climatic zones we adopt, we should certainly abandon the word *temperate* altogether as the designation of the middle zone in each hemisphere, and substitute some such adjective as *intermediate* for it. The words *torrid* and *frigid* should likewise disappear, and be replaced by *tropical* or *equatorial,* and *polar.*

Necessary Subdivisions of the Zones. However we may classify them, the climatic zones are far from

being uniform in character throughout their whole extent. Hence, no brief, simple description of the climate of a zone can be given. For this reason, suggestions have been made regarding subdivisions of the different zones. Thus, in the case of the classic north temperate zone, it has been proposed to subdivide it into sub-tropical, temperate, and sub-arctic, but the question how to limit these subdivisions is difficult to settle. A more rational scheme is that which, in view of the great differences in the climatic relations of land and water, recognises a first large subdivision of each zone into land and water areas. Then, as continental interiors differ from coasts, and as windward coasts have climates unlike those of leeward coasts, a further natural subdivision would separate these different areas. Finally, the control of altitude over climate is so marked that plateaus and mountains may well be set apart by themselves as separate climatic districts. If each of the zones, whether bounded by latitude circles, or by isotherms, or by wind systems, be considered under these general subdivisions, as close an approach to actual conditions of climate will be made as is possible in general description. Obviously, however, when the larger zones are subdivided to such an extent as is here suggested, we are dealing with a classification of climates rather than with climatic zones.

CHAPTER II

THE CLASSIFICATION OF CLIMATES

Need of a Classification of Climates—Relation of Continental and Ocean Areas to Temperature: Reasons for the Slow Change in the Temperature of Ocean Waters—Marine or Oceanic Climate—Continental Climate—Desert Climate—Coast or Littoral Climate—Monsoon Climate—Mountain and Plateau Climate—Mountains as Climatic Divides.

Need of a Classification of Climates. A broad division of the earth's surface into zones is necessary as a first step in any systematic study of climate, but it is not satisfactory when a more detailed discussion is undertaken. The reaction of the physical features of the earth's surface upon the atmosphere complicates the climatic conditions found in each of the zones, and makes further subdivision desirable. Under the control of these different physical conditions, the climatic elements unite to produce certain fairly distinct types of climate, and these may be classified in various ways. The usual method is to separate the *continental* (near sea-level) and the *marine.* An extreme variety of the continental is the *desert;* a modified form, the *littoral;* while altitude is so important a control that *mountain* and *plateau* climates are further grouped by themselves.

Relation of Continental and Ocean Areas to Temperature. Land and water differ greatly in their behaviour regarding absorption and radiation. The former warms and cools readily, and to a considerable degree; the latter, slowly and but little. (1) Of the insolation which falls upon the ocean, a good deal is at once reflected, and is therefore not available for warming the water. Land surfaces, on the other hand, are poor reflectors; but little insolation is lost in that way; hence more energy is available for raising their temperature. (2) Most of the insolation which enters the water is transmitted to some depth, and, therefore, is not effectively applied to warming the surface. Land is opaque and does not allow the incident insolation to pass beyond a comparatively thin surface stratum; hence this surface can be well warmed. (3) The evaporation of water requires a large amount of energy, which changes the state of the water without raising its temperature (latent heat). Land, although often moist, is itself non-volatile; therefore the loss of energy in the process of evaporation is usually very slight. (4) Water is more difficult to warm than any other natural substance, while land is warmed easily and quickly. If equal amounts of heat are received by equal areas of land and water, the former warms about twice as much as the latter. (5) The mobility of water keeps the warmer and the colder portions well mixed, and therefore greatly retards the process of warming any one portion of the surface. Land cannot thus equalise

its temperature. (6) The cloudiness over the oceans is usually greater than that over the lands, and this operates to shade the former more than the latter, reducing the energy available for warming the water surface. For these various reasons, ocean surfaces can warm but little during the day, or in summer, and can cool but little during the night, or in winter. They, and the air over them, are therefore conservative as regards their temperatures. Land areas, and the air over the lands, on the other hand, warm and cool readily. The influence of latitude, as seen in solar climate, is not infrequently wholly overcome by the influence of land and water.

Marine or Oceanic Climate. Conservatism in its temperature conditions is the most distinctive feature of a marine climate. The results of the *Challenger* Expedition show that the diurnal range of air temperature over the ocean between latitudes 0° and 40° averages only 2° or 3°. Further, the slow changes in temperature of the ocean waters involve a retardation in the times of occurrence of the maxima and minima, and a marine climate, therefore, has characteristically a cold spring and a warm autumn, the seasonal changes of temperature being but slight. The surface waters of oceans and lakes average somewhat warmer than the air over them, and for this reason all considerable bodies of water which remain unfrozen in winter become sources of warmth for the adjacent lands during the colder months. Characteristic, also, of marine climates is a prevailingly higher

relative humidity, a larger amount of cloudiness, and a heavier rainfall than is found over continental interiors. All of these features have their explanation in the abundant evaporation from the ocean surfaces. In the middle latitudes, again, there is this contrast between the oceans and the continental interiors, that the former have distinctly rainy winters, while over the latter the colder months have a minimum of precipitation. Ocean air is cleaner and purer than land air, and ocean air is, on the whole, in more active motion, because friction of air on water is less than friction of air on land.

It is obvious that an equable, damp, and cloudy climate, such as that which is, on the whole, typical of the oceans and of their leeward coasts, must affect vegetation in a way quite different from that noted in a hotter and drier climate, with greater variations of temperature. Thus Schindler has shown that wheat contains less protein in a marine climate, and hence more meat, leguminous plants, and other nitrogenous foods are necessarily eaten. An interior climate, like that of southern Russia and Hungary, produces wheat which is richer in protein; the need of other nitrogenous foods is consequently decreased. The proportion of starch is decreased, and that of gluten is increased, in a hot, dry climate. The size of the crop is also affected by the climate.

Continental Climate. Marine climate is equable; continental, is severe. The annual temperature ranges increase, as a whole, with increasing distance

from the ocean; the regular diurnal ranges are also large, reaching 35° or 40°, and even more, in the arid

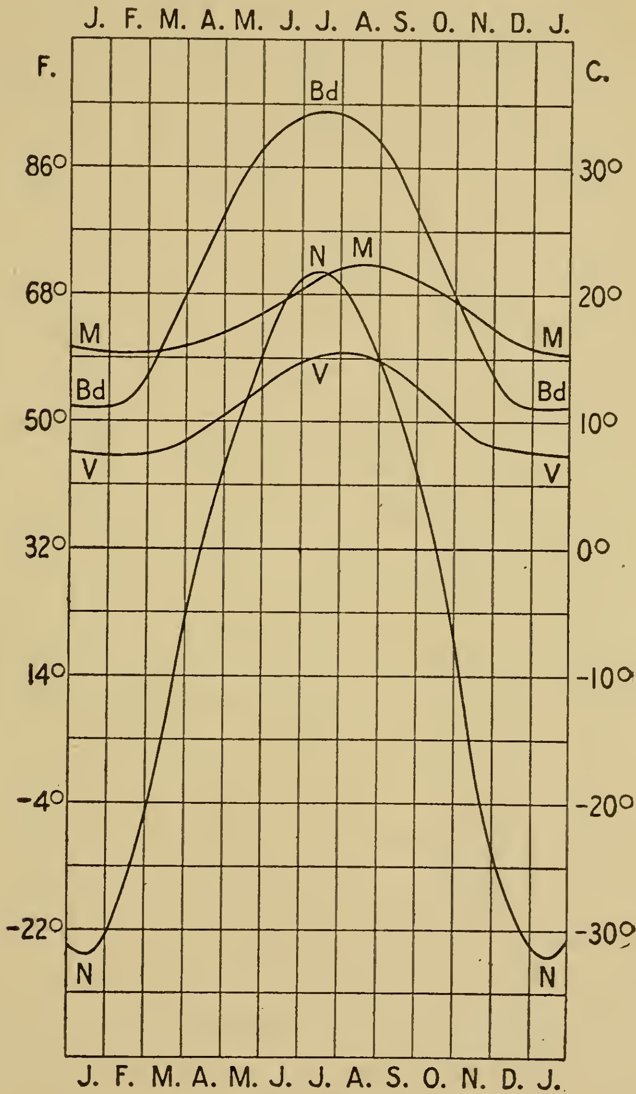

FIG. 7. INFLUENCE OF LAND AND WATER ON THE ANNUAL MARCH OF AIR TEMPERATURE

continental interiors. The coldest and warmest months are usually January and July, the times of

maximum and minimum temperatures being less retarded than in the case of marine climates. April is usually warmer than October, unless spring warming is delayed by the melting of a snow-cover. In the latter case, the snow-covered land surface temporarily takes on the characteristics of a water surface, and has a retarded spring. The greater seasonal contrasts in temperature over the continents than over the oceans are furthered by the less cloudiness over the former. The clearer continental skies of high latitudes favour a lowering of the winter, but a slight rise of the summer temperatures, while in lower latitudes the clearer summer skies favour a higher mean annual temperature. Diurnal and annual changes of nearly all the elements of climate are greater over continents than over oceans; and this holds true of irregular, as well as of regular, variations. The contrast between marine and continental climates in the matter of the annual march of temperature is shown in Figure 7. In low latitudes, the curve for Funchal, on the island of Madeira (M), represents the marine type, and that for Bagdad, in Asia Minor (Bd), the continental. For higher latitudes, the curves for Valentia (V), a coast station in the south-west of Ireland, and for Nerchinsk (N), in eastern Siberia, are representatives of the two types.

Owing to the distance from the chief source of supply of water-vapour—the oceans—the air over the larger land areas is naturally drier and dustier

than that over the oceans. Yet even in the arid continental interiors in summer, the absolute vapour content is surprisingly large, although the air is still far from being saturated. In the hottest months the percentages of relative humidity may reach 20% or 30%. At the low temperatures which prevail in the winter of the higher latitudes, the absolute humidity is very low, but, owing to the cold, the air is often damp. Cloudiness, as a rule, decreases inland, reaching its minimum in deserts. And with this lower relative humidity, more abundant sunshine and higher temperature, the evaporating power of a continental climate is much greater than that of the more humid, cloudier, and cooler marine climate. Actual evaporation is, however, under these conditions, usually much less than the possible evaporation which would take place were there more water present to be evaporated. Both amount and frequency of rainfall, as a rule, decrease inland, but the conditions are very largely controlled by local topography and by the prevailing winds. The decreased frequency of rainfall on the lowlands is especially marked in winter. Winds average somewhat lower in velocity, and calms are more frequent, over continents than over oceans. The seasonal changes of pressure over the former give rise to systems of inflowing and outflowing, so-called continental, winds, sometimes so well developed as to become true monsoons. Usually, however, the changes in direction and the development are not very marked.

In winter, clear, crisp days, which are followed by cold, calm nights, and interrupted from time to time by spells of cloudy, windy weather, with or without light precipitation; in summer, clear, calm nights, followed by hot days with increasing wind velocity and heavy clouds towards noon, and often by thunderstorms later in the afternoon—these are typical weather conditions of continental interiors in the higher latitudes; and they are of much interest to man. The extreme temperature changes which occur over the continents are the more easily borne because of the dryness of the air; because the minimum temperatures of winter occur when there is little or no wind, and because, during the warmer hours of the summer, there is the most air movement.

Desert Climate. An extreme type of continental climate may be found in deserts. It is a curious fact that desert and marine climates—the two extremes of the climatic scale—resemble one another in some respects. Desert air, though often dusty by day, is notably free from micro-organisms; the purity of ocean air is well known. Again, deserts and oceans alike have high wind velocities. The large diurnal temperature ranges of inland regions, which are most marked where there is little or no vegetation, give rise to active convectional currents during the warmer hours of the day. Hence high winds, disagreeable because of the dust and sand which they carry, are common by day, while the nights are apt to be calm and relatively cool. Travelling by day is

unpleasant under such conditions. Diurnal cumulus clouds, often absent because of the excessive dryness of the air, are thus replaced by clouds of blowing dust and sand. This sand, often carried afar, may find a resting-place on the moister lands to leeward. Thus beds of loess are formed. Indeed, many geological phenomena, and special physiographic types of varied kinds, are associated with the peculiar conditions of desert climate. The excessive diurnal ranges of temperature cause rocks to split and break up. Wind-driven sand erodes and polishes the rocks. When the separate fragments become small enough, they, in their turn, are transported by the winds and further eroded by friction during their journey. The ground is often swept clean by the winds. Curious conditions of drainage result from the deficiency in rainfall. Rivers "wither" away, or end in sinks or brackish lakes. Desert plants protect themselves against the attacks of animals by means of thorns, and against evaporation by means of hard surfaces and an absence of leaves. The life of man in the desert is likewise strikingly controlled by the climatic peculiarities of strong sunshine, of heat, and of dust. Occasionally heavy downpours of rain (cloud-bursts) over mountains or on the borders of deserts, cause sudden floods. Even slight rainfalls in deserts awaken multitudes of dormant plant seeds.

Coast or Littoral Climate. Between the pure marine and the pure continental types, the coasts furnish almost every grade of transition. Hence coast

or littoral climates may well be placed in a group by themselves. Prevailing winds are here important controls. When these blow from the ocean, as on the western coasts of the temperate zones, the climates are more marine in character; but when they are off-shore, as on the eastern coasts of these same zones, a somewhat modified type of continental climate prevails, even up to the immediate sea-coast. Hence the former have a much smaller range of temperature; their summers are more moderate and their winters milder; extreme temperatures are very rare; the air is damp; there is much cloud. All these marine features diminish with increasing distance from the ocean, especially when there are mountain ranges near the coast, as is the case in the western United States and in Scandinavia. In the tropics, windward coasts are usually well supplied with rainfall, and the temperatures are modified by sea breezes. Leeward coasts in the trade wind belts offer special conditions. Here the deserts often reach the sea, as on the western coasts of South America, Africa, and Australia. Cold ocean currents, with prevailing winds along shore rather than onshore, are here hostile to rainfall, although the lower air is often damp, and fog and cloud are not uncommon.

Monsoon Climate. Exceptions to the general rule of rainier eastern coasts in trade wind latitudes are found in the monsoon regions, as in India, for example, where the western coast of the peninsula is abundantly watered by the wet south-west monsoon.

As monsoons often sweep over large districts, not only coast but interior, a separate group of monsoon climates is desirable. In India, there are really three seasons—one cold, during the winter monsoon; one hot, in the transition season; and one wet, during the summer monsoon. Little precipitation occurs in winter, and that chiefly in the northern provinces. The high temperatures of the transition periods are most oppressive when the air is most damp. In India this is the case in the autumn. In low latitudes, monsoon and non-monsoon climates differ but little, for summer monsoons and regular trade winds both give rains, and wind direction has slight effect upon temperature.

The winter monsoon is offshore, and the summer monsoon onshore, under typical conditions, as in India. But exceptional cases are found where the opposite is true. Thus, on the north-western coast of Japan, the north-eastern coasts of Formosa and of the Philippines, and the eastern coasts of the southern Deccan and of Ceylon, the prevailing offshore, winter, dry monsoon becomes an onshore, rainy wind. Many complicated cases of this kind are not easily co-ordinated. In higher latitudes, the seasonal changes of the winds, although not truly monsoonal, involve differences in temperature and in other climatic elements. The eastern coast of the United States has prevailing cold, dry, clear winds from the continental interior in winter, while the prevailing winds of summer are south-west, and hence warm and often moist.

The only well-developed monsoons on the coast of the continents of higher latitudes are those of eastern Asia. These are offshore during the winter, giving dry, clear, and cold weather; while the onshore movement in summer gives cool, damp, and cloudy weather. Without these seasonal winds the winters would have the maximum amount of rain and cloud.

Mountain and Plateau Climate. Both by reason of their actual height and because of their obstructive effects, mountains influence climate similarly in all the zones. Hence mountain and plateau climates are placed in a group by themselves, as distinguished from those of lowlands. The former, as contrasted with the latter, are characterised by a decrease in pressure, temperature, and absolute humidity; an increased intensity of insolation and radiation; larger ranges in soil temperature; usually a greater frequency of percipitation, and, up to a certain altitude, more of it.

At an altitude of 16,000 ft., more or less, pressure is reduced to about one-half of its sea-level value. The highest human habitations are found under these conditions. While the pressures and the pressure changes at sea-level have no marked effect upon man, the physiological effects of the decreased pressure aloft (faintness, nausea, headache, weakness) are experienced by a majority of people at altitudes above 12,000 to 15,000 ft. The symptoms, and the height at which they appear, vary much in different cases, and depend upon the physical condition of the indi-

vidual, the weather, bodily exertion, and so on. The greatest altitudes attained by man were reached by balloon, and in such cases a supply of oxygen is usually taken up by the aëronaut. Man endures the rapid pressure changes during balloon ascents with difficulty, and often only with considerable suffering. The eagle and the condor, however, suffer no inconvenience during their high flights.

It has been suggested by Jourdanet that mountain and plateau climates be divided into groups, *climats de montagne,* below 6500 feet, and *climats d'altitude,* above that height. The former are beneficial because of the stimulating quality of their clean, cool air; the latter may be injurious because of the low pressure. The variations in pressure, as well as the actual pressures, diminish aloft. On high mountains and plateaus, the pressure is lower in winter than in summer, owing to the fact that the atmosphere is compressed by cold to lower levels in the winter, and is expanded upwards in summer by heat. The morning minimum pressure on mountains is usually the primary minimum, the afternoon minimum being less marked and coming later than on lowlands. Figure 8 shows the diurnal variation of pressure at Geneva (408 meters, G), Berne (573 meters, B), on the Säntis (2467 meters, S), and on the summit of Mont Blanc (4811 meters, MB), and illustrates well the general characteristics of the curves found at different altitudes. Local topography, however, is an important controlling influence, and modifies such curves very much.

The intensity of insolation and of radiation both increase aloft in the cleaner, purer, drier, and thinner air of mountain climates. The sun usually shines more often and more powerfully at high altitudes. The

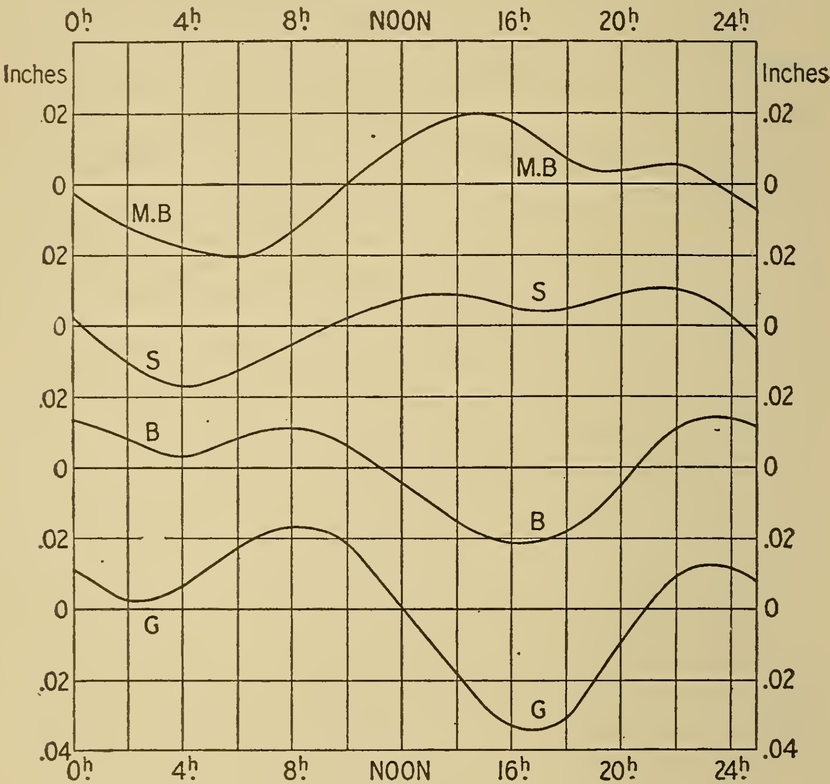

FIG. 8. DIURNAL VARIATION OF PRESSURE: INFLUENCE OF ALTITUDE

intensity of the sun's rays attracts the attention of mountain-climbers at great altitudes. The excess of surface temperature over air temperature also increases aloft, and is a favourable element in plant growth. There is likewise an increase in the range of surface temperature, although this is much influenced

by exposure. The vertical decrease of temperature, which is also much affected by local conditions, is especially rapid during the warmer months and hours; mountains are then cooler than lowlands. The inversions of temperature characteristic of the colder months, and of the night, give mountains the advantage of higher temperature then, a fact of importance in connection with the use of mountains as winter resorts. At such times, the cold air flows down the mountain sides and collects in the valleys below, being replaced by warmer air aloft. Hence diurnal and annual ranges of temperature on the mountain tops of middle and higher latitudes are lessened, and the climate in this respect resembles a marine condition; but topography and the conditions of local clouds and winds are here important controls. The times of occurrence of the maximum and minimum are also much influenced by local conditions. Figure 9 shows the diurnal march of temperature for Paris (solid) and the Eiffel Tower (broken) in January and July. It will be noted that the times of maximum and minimum are retarded on the Eiffel Tower, and that the range is less than at the earth's surface. These are characteristics of mountain climates. Elevated, well-enclosed valleys, with strong sunshine, often resemble continental conditions of large temperature range; and plateaus, as compared with mountains at the same altitude, have relatively higher temperatures and larger temperature ranges. Altitude tempers the heat of the low latitudes. High

mountain peaks, even on the equator, can remain snow-covered the year around; the plateau of south-

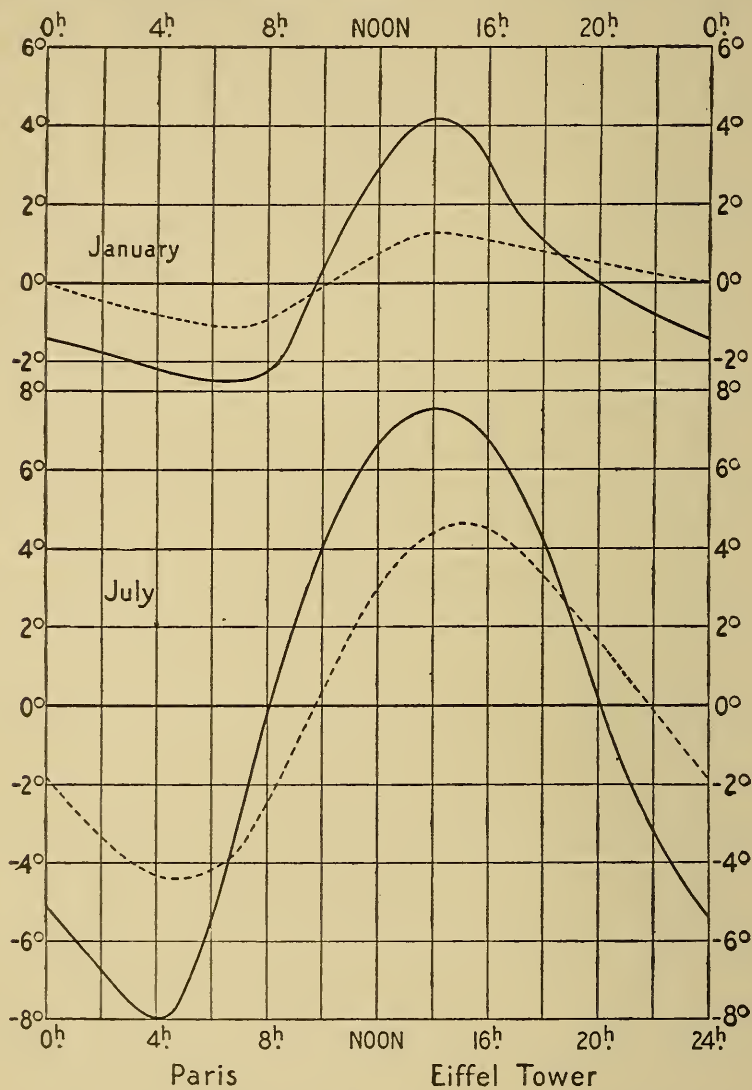

FIG. 9. DIURNAL VARIATION OF TEMPERATURE: INFLUENCE OF ALTITUDE

ern India, at 6000 to 7000 ft. above sea-level, always has moderate mean temperature, and from the dense

jungle of the tropical lowland to the snowy mountain top, successive zones of vegetation are encountered.

Nine-tenths of the water vapour in the atmosphere are below 21,000 feet. Hence mountains are important vapour barriers, and one side may be damp while the other is dry. Curiously mistaken ideas of distance often result from the remarkable clearness and dryness of the air on high mountains. No general law governs the variations of relative humidity with altitude, but on the mountains of Europe the winter is the driest season, and the summer the dampest. At well-exposed stations there is a rapid increase in the vapour content soon after noon, especially in summer. The same is true of cloudiness, which is often greater on mountains than at lower levels, and is usually at a maximum in summer, while the opposite is true of the lowlands in the temperate latitudes. One of the great advantages of the higher Alpine valleys in winter is their small amount of cloud. This, combined with their low wind velocity and strong insolation, makes them desirable winter health resorts. Latitude, altitude, topography, and winds are determining factors in controlling the cloudiness on mountains. In intermediate latitudes there is a seasonal migration of the level of maximum cloudiness, and of maximum relative humidity, from the lowlands in winter to higher altitudes in the warmer months, in association with the diurnal convectional movements of the warmer season. Frequent

rapid local changes also occur. In the rare, often dry, air of mountains and plateaus, evaporation is rapid, the skin dries and cracks, and thirst is increased.

Rainfall usually increases with increasing altitude up to a certain point, beyond which, owing to the loss of water vapour, this increase stops. The zone of maximum rainfall averages about 6000 to 7000 feet in altitude, more or less, in intermediate latitudes, being lower in winter and higher in summer. Mountains usually have a rainy and a drier side; the contrast between the two is greatest when a prevailing damp wind crosses the mountain, or when one slope faces seaward and the other landward. When the prevailing winds differ little in dampness, this contrast is lessened, and there may then be a very close correspondence between the rainfall and the topographic map of a region. Mountains often provoke rainfall, and local "islands," or, better, "lakes," of heavier precipitation result. Such are found on the mountains of the Sahara, and of other deserts. This local precipitation favours the growth of vegetation; small streams and oases are found, and temporary camps, or more permanent settlements, of the nomadic tribes of the desert are there established. Well-marked zones of vegetation are noted under such conditions, as in the transition from the dry Californian lowlands up through the deciduous, and then the coniferous, forests of the Sierra Nevada to the snows on the summits. Similarly, the high plateaus of southern Utah and of Arizona are high enough to re-

ceive fairly abundant rainfall, while the lowlands are arid.

Mountains resemble marine climates in having higher wind velocities than continental lowlands; mountain summits have a nocturnal maximum of wind velocity, while plateaus usually have a diurnal maximum. Mountains both modify the general, and give rise to local, winds. Among the latter, the well-known mountain and valley winds are often of considerable hygienic importance in their control of the diurnal period of humidity, cloudiness, and rainfall, the ascending wind of daytime tending to give clouds and rain aloft, while the opposite conditions prevail at night. The high temperature and dryness of the *foehn,* which is of immense benefit to man by reason of its melting and evaporating powers, although often enervating and depressing, result from the fact of a descent of the air from a mountain slope or summit. The bora, with its cold gust, is a wind in whose development a mountain or plateau is essential. And the mistral of southern France owes some of its cold to radiation over the interior plateaus.

Mountains as Climatic Divides. Very different conditions of temperature, pressure, and humidity may be found on the opposite sides of a well-defined mountain range, because such a range interferes with the free horizontal interchange of the lower air. Mountain ranges which trend east and west, like the Alps and the Himalayas, separate more severe from less severe climates; those which follow a coast-line, as

in California, Scandinavia, or eastern Siberia, separate marine from continental. Large differences of pressure on the two sides may be equalised by a flow of air across the mountain, as in the *foehn*.

CHAPTER III

THE CLASSIFICATION OF CLIMATES (*Continued*)

Supan's Climatic Provinces—Köppen's Classification of Climates—Ravenstein's Hygrothermal Types—Classification of Rainfall Systems—Herbertson's Natural Geographical Regions—Summary and Conclusions.

Supan's Climatic Provinces. The ordinary classification into continental, marine, and mountain climates is too general. Some scheme of classification is needed in which the geographical factor plays an important part, and which recognises the types of climate, possessing common characteristics of temperature, rainfall, and winds, that occur over areas having similar topographic conditions. A fairly simple scheme of this kind has been suggested by Supan, who recognises thirty-five so-called climatic provinces, but any such rigid subdivision is obviously susceptible of almost infinite modification. Twenty-one of these provinces are in the eastern hemisphere, including Polynesia; twelve are in the western, and two in the polar zones. The description of these provinces is as follows:[1]

1. Arctic Province. This coincides with the

[1] Free translation of original, following Bartholomew's *Atlas of Meteorology,* p. 7.

north polar cold cap, the area wherein the mean temperature of the warmest summer month is never over 50° F., and within which trees do not grow.

2. West European Province. Mild winters, owing to influence of the westerly winds and Gulf Stream. Yearly temperature range under 59° F.

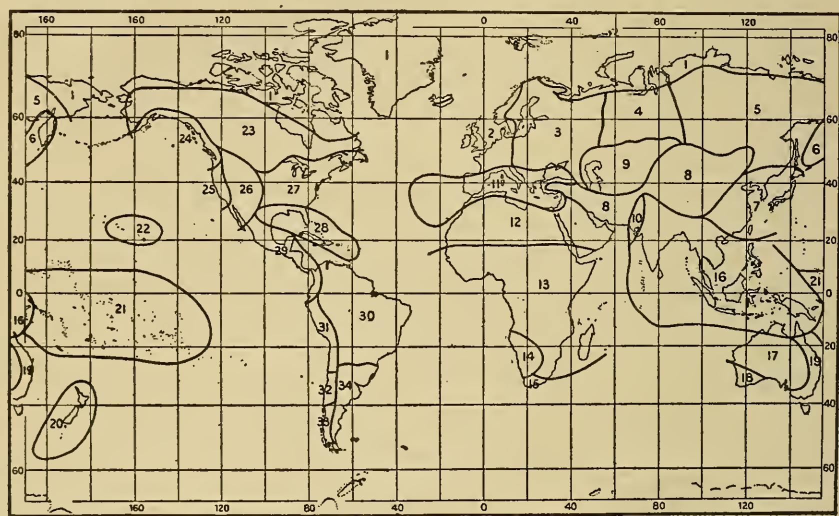

FIG. 10. SUPAN'S CLIMATIC PROVINCES

(15° C.). Plentiful rainfall, fairly well distributed throughout the year, but varying in quantity owing to great diversity of land contours. The climatic conditions often vary in short distances, and hence the region can be divided into many subdivisions.

3. East European Province. Here the evidences of a land climate begin to be observed; but as most of the region is a plain, differences depend mainly on latitude. The rainfall is smaller than in Province 2,

and gradually diminishes towards the southeast, and has a marked summer maximum.

4. West Siberian Province. This is separated from 3 by the limit of the positive annual isanomalous lines, which practically coincide with the Urals. The characteristic peculiarities of 3 are found here greatly emphasised, and the greater variability of temperature is to be noted.

5. East Siberian Province. A gradual rising of the ground is found east of the Yenisei, with low plains only along the rivers. The winter cold pole is here, and the yearly range of temperature is a maximum. As a rule, the rainfall is small.

6. Kamchatkan Province. The sea diminishes the temperature extremes noted in Province 5, and much rain falls.

7. Sino-Japanese Province. On the continent, relatively well-marked winter cold, and strong periodical rains. In Japan, these peculiarities are less extreme.

8. Asiatic Mountain and Plateau Province. This includes all the lofty plateaus bounded by mountain ranges, which shield it on every side, and so render it very dry. The great height makes the winter temperature severe; but the summer heat is great, owing to the continental position. The daily, as well as the yearly, range of temperature is very marked.

9. Aral Province. Dry, low-lying plain, with the greatest rainfall in the north in summer, and in the

south in winter. The plains of western Turkestan have severe winters and very hot summers.

10. Indus Province. A plain remarkable for great dryness and heat.

11. Mediterranean Province. Very varied in climate, owing to its great irregularity of outline, both horizontal and vertical. Mild, except on high plateaus. Winter rains.

12. Saharan Province. Reaches to Mesopotamia. Region of dry, north winds, and probably the one receiving least rain. Its continental position and lack of vegetation increase the heat of summer extraordinarily; both annual and daily ranges of temperature are considerable.

13. Tropical African Province. Owing to the height of the central plateau, the heat is less intense, but it is very great on the narrow coastal plains. Tropical rains decreasing towards the west.

14. Kalahari Province. Includes all the almost rainless region of southwest Africa.

15. Cape Province. Sub-tropical.

16. Indo-Australian Monsoon Province. Strong, periodical rains are brought with the southwest and northwest monsoons, except at a few places in the archipelago. The temperature is fairly uniform, despite the great extent of the province, and the yearly range is very small.

17. Inner Australian Province. With great extremes of temperature. Irregular and rare rains.

18. Southwest Australian Province. Sub-tropical.

19. East Australian Province. It extends to the water-parting and includes the southeast coast and Tasmania. Plentiful and fairly regular rains. Moderate range of temperature.

20. New Zealand Province. Probably includes the small neighbouring islands. Mild climate, with fairly regular rains.

21. Tropical Polynesian Province. Tropical climate, ameliorated by the ocean, so that mild summer weather prevails throughout the year. On the loftier islands, the rain is abundant, and has a tropical periodicity.

22. Hawaiian Province. Also a mild climate, but with sub-tropical rains.

23. Hudson (North Canadian) Province. Great extremes of temperature and little precipitation.

24. Northwest American Coastal Province. Mild, equable, rainy climate.

25. Californian Province. Relatively cool, especially in summer. Marked sub-tropical rainy seasons.

26. North American Mountain and Plateau Province. Great yearly and daily ranges. Dry.

27. Atlantic (East North American) Province. Great contrast in temperature conditions of north and south in winter. Extreme climate even on the coast. Plentiful rains, evenly distributed throughout the year. Great variability.

28. West Indian Province. This also includes the southern rim of North America. Equable tem-

perature. Rain at all seasons, but with a marked summer maximum.

29. Tropical Cordilleran Province. On the interior plateau, perpetual spring, owing to considerable height above sea-level. In Mexico and Central America, marked zenithal rains; in South America, more regular precipitation.

30. South American Tropical Province. Little that is certain is known about this province, which includes mountainous regions and plains, and ought, therefore, to possess considerable variety of climate.

31. Peruvian Province. This province extends as far south as 30° S., and so includes the northern part of Chile. Abnormally cool. Rainless.

32. North Chilean Province. Sub-tropical.

33. South Chilean Province. Equable temperatures, with cool summers. Extraordinarily rainy.

34. Pampa Province. Range of temperature fairly large, especially in the north. Rain not plentiful.

35. Antarctic Province. Resembles the Arctic, so far as can at present be determined, in winter cold but differs in having a very low summer temperature and a very regular distribution of pressure and winds.

Fig. 10 shows the geographical distribution of these climatic provinces.

Köppen's Classification of Climates. An interesting classification of climates, from a botanical standpoint, is that proposed by Köppen. This rests upon certain critical values of the temperature and rain-

fall of the warmest or coldest, or of the wettest and driest month. The plant classification proposed by A. de Candolle in 1874, and later adopted by Drude, is accepted. This is a division into five principal biological groups under the control of temperature and moisture, as follows:

A. *Megatherms:* plants which need continuously high temperature without much annual range, and also abundant moisture. There is no cool season; the temperature of the coolest month is over 64.5° (18° C.), and there is at least one month of heavy rain. When there are marked dry seasons, the principal one comes in winter and spring. In parts of this belt there are two rainy seasons. In this belt are found the lofty tropical forests intertwined with vines and creepers—sago, betel, pepper, cacao, bread-fruit, baobab, coffee, sugar-cane, banana, ginger, and so on.

B. *Xerophytes:* plants which like dryness and need high temperatures, at least for a short season. These are found in tropical districts which have a long dry season, and in the steppes and deserts of the tropics and of the warmer parts of the temperate zones. They are adapted in various ways for life in a dry climate; they rest during the dry time, and, in extreme cases, where rain may not fall for years, they survive as seeds. The vegetation varies with the soil. In this group we find the date, mesquite, acacia, cactus, agave, and similar plants.

C. *Mesotherms:* need moderate heat (59°–68°) and a moderate amount of moisture; some require

high summer temperatures; others shun low winter temperatures; others shun the dryness which often accompanies high summer temperatures. These plants inhabit latitudes between 22° and 45° N. or 40° S., so long as the moisture continues sufficient. There is a cool season—coldest month below 64.5° (18° C.)—and a hot summer—warmest month over 72° (22° C.),—or a mild winter—coldest month over 43° (6° C.)—or both. The classic Mediterranean climate is found in this belt. The mesotherm belt contains the tea, maté, rice, cotton, magnolia, hickory, arbor vitæ, hemlock, wheat, corn, olive, fig, grape, heath, cinchona, etc.

D. *Mikrotherms:* need less heat, lower mean annual temperature, cooler and shorter summers, and colder winters. The warmest month is at least 50° (10° C.) and not over 72° (22° C.); the coldest is below 43° (6° C.), with at least an occasional snow-cover in winter and sufficient rainfall in the warmer season. Evergreen and deciduous forests, grains, and, in the warmer portions, fruit and corn are found.

E. *Hekistotherms:* plants of the Arctic zone, beyond the limits of tree growth and of the zone of scrubby Antarctic vegetation. These need the least heat. Mosses, lichens, and similar lowly forms are typical.

A simple scheme of distribution of these five groups of plants may first be developed with reference to an ideal continent, stretching from pole to pole, with oceans on both sides and without mountains (Fig.

11). Here *a a* is the western and *b b* the eastern coast. The approximate latitudes are given at the margins. The groups of de Candolle's system are arranged as shown, if the xerophytes are limited to

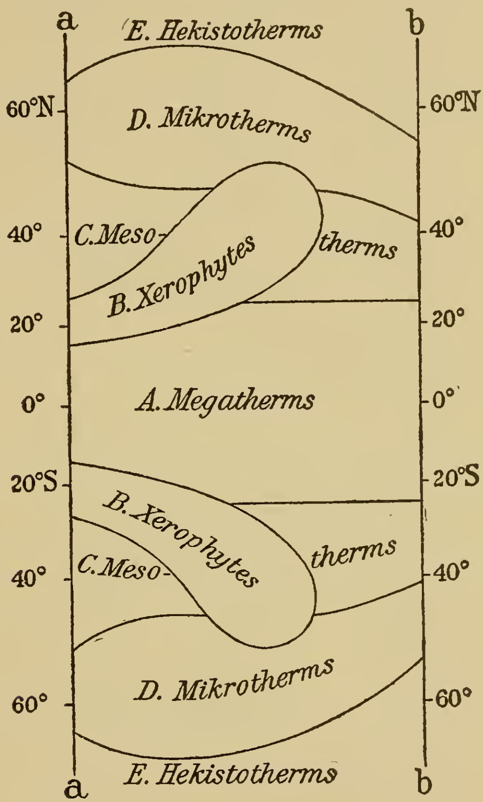

FIG. II. GENERAL DISTRIBUTION OF PLANT ZONES

the deserts and steppes, and if those woody plants of the megatherm and mesotherm zones which are adapted to a dry climate are included within these zones. The typical zonal arrangement is interrupted in latitudes 20° to 50° by the fact that the arid dis-

trict of the xerophytes (B) is wedged in on the west coast between A and C. Farther east, zone B broadens poleward, cuts through the middle of the mesotherm zone, and usually ends without reaching the east coast.

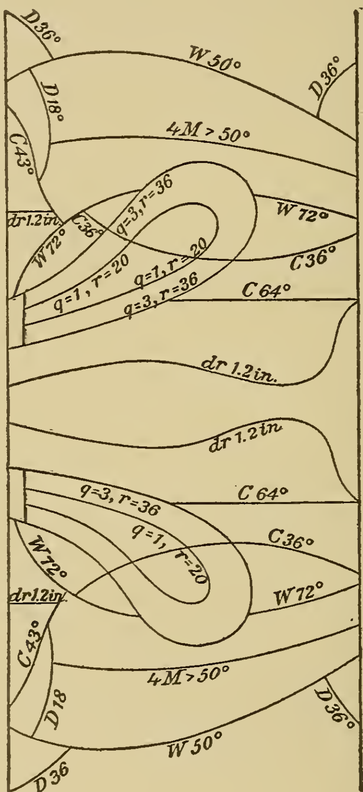

FIG. 12. SCHEME OF CLIMATES AT SEA-LEVEL

The five principal types are further subdivided until the whole number of climates reaches twenty-four. The special conditions which characterise each climate are carefully determined, and each sub-climate is named after one of its characteristic plants or ani-

mals; or after some distinctive meteorological phenomenon; or, again, after the general character of its vegetation. Fig 12 gives the limits of the different

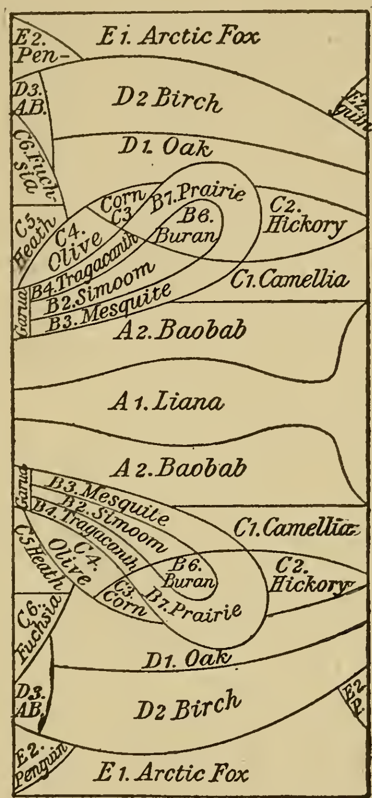

FIG. 13. NAMES OF CLIMATES AT SEA-LEVEL

sub-climates, and also the characteristic conditions of temperature and precipitation.[1] Fig. 13 gives the

[1] Figures are degrees Fahr. C = coldest month. W = warmest month. 4 M = 4 months. dr. 1.2 in. = driest month rainfall 1.2 inches. D. 18° and D 36° = difference between extreme months 18° and 36°. q = quotient obtained by dividing the amount of rainfall in the wettest month (in mm.) by the maximum vapour-tension (in mm.) at the mean temperature of the same month, an

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scheme of the sub-climates for the lowlands, with their names. Four climates which do not occur at sea-level are here lacking (C7, E3, E4, F).[1] The verti-

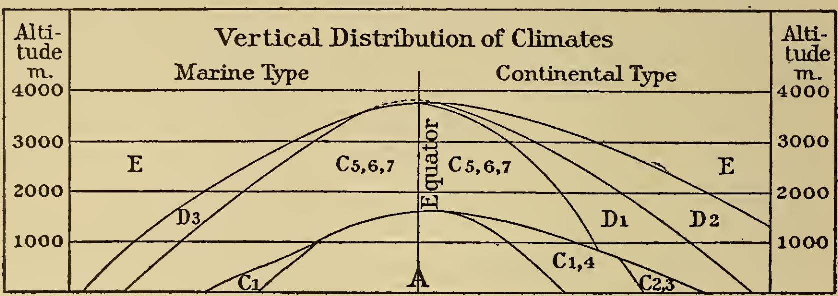

FIG. 14. VERTICAL DISTRIBUTION OF CLIMATES

cal distribution of these climates, much simplified, is shown in Fig 14. The descent of the climatic strata from equator to higher latitudes is shown on the right for the continental, and on the left for the marine type, as far as about latitude 57°. Climates C1 to C4, and D1 and D2, have large temperature ranges, and are therefore lacking at the equator and on the ocean; while C5 to C7, and D3, have small ranges, and are not found on the continents in higher latitudes. The general control of pressure, winds, and ocean currents over the climatic types is shown in the two following ideal diagrams, in which the two vertical lines indicate the west and east coasts of the ideal continent, and the area included reaches to the middle of the ad-

expression which combines the effect of rainfall and evaporating power. r = rain probability of rainiest month.

[1] C7, High savanna climate; E3, Yak, or Pamir climate; E4, Chamois or high alpine climate; F, perpetual frost, without life.

jacent ideal oceans. The line 0°–0° is the equator (Figs. 15 and 16). The short arrows give the wind direction 500–1000 metres above the surface; calms are represented by the sign ⊙ ; the long broken arrows

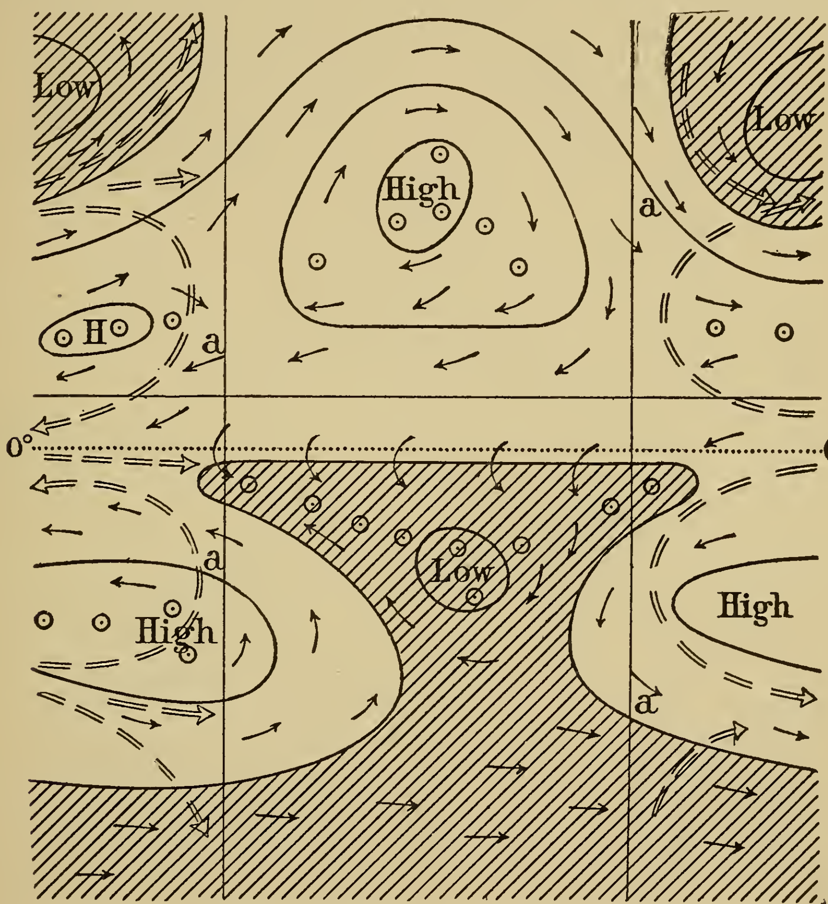

Fig. 15. Pressure and Winds in January

indicate the prevailing surface ocean currents. At *a a* there is a rise of cold water from beneath the surface of the ocean. The curving lines are sea-level isobars; the lower pressures are shaded. The letters and

boundaries, drawn in short, slanting lines in Fig. 16 indicate the climatic districts of Fig. 11. Fig. 15 is similar to Fig. 16, as far as these climatic districts are

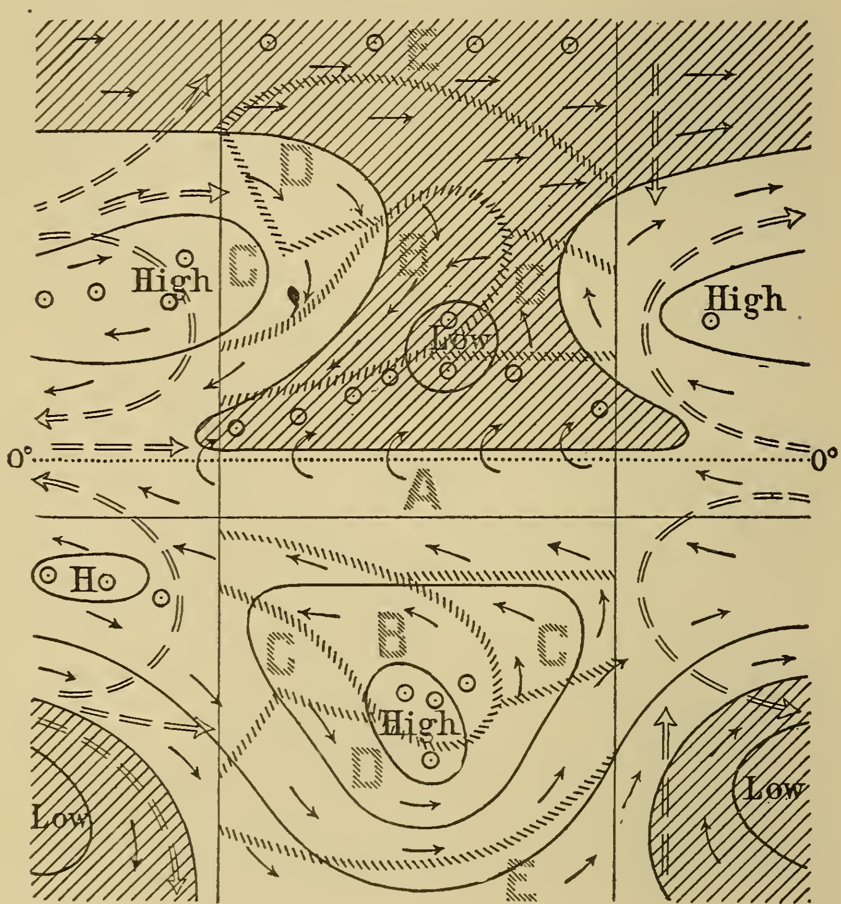

Fig. 16. Pressure and Winds in July

concerned. Therefore the letters and boundaries are omitted. Fig. 17 shows the geographical distribution of the climatic types and sub-types.

Ravenstein's Hygrothermal Types. Recognising

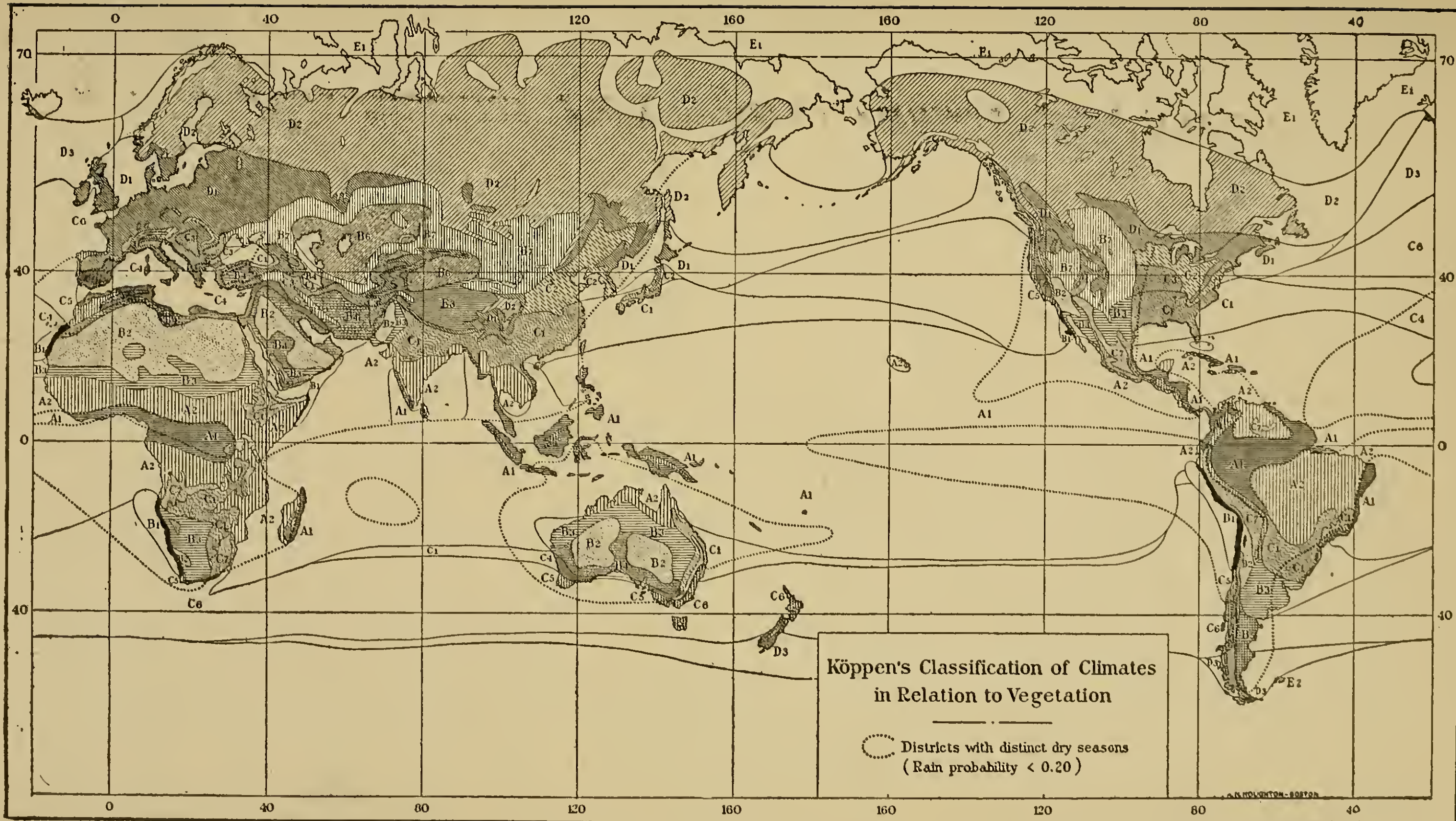

FIG. 17. KÖPPEN'S CLASSIFICATION OF CLIMATES IN RELATION TO VEGETATION

the importance of relative humidity as a climatic factor in its influence upon life, upon agriculture and upon industry, and basing his grouping of climates upon certain relations between temperature and relative humidity, Ravenstein proposes a subdivision of the earth's surface into sixteen *hygrothermal* climatic types. The general characteristics and examples of these types are as follows:

1. Hot (73° and over) and very damp (humidity 81% or more): Batavia, Cameroons, Mombasa.
2. Hot and moderately damp (66–80%): Havana, Calcutta.
3. Hot and dry (51–65%): Bagdad, Lahore, Khartum.
4. Hot and very dry (50% or less): Disa, Wadi Halfa, Kuka.
5. Warm (58° to 72°) and very damp: Walfish Bay, Arica.
6. Warm and moderately damp: Lisbon, Rome, Damascus, Tokio, New Orleans.
7. Warm and dry: Cairo, Algiers, Kimberley.
8. Warm and very dry: Mexico, Teheran.
9. Cool (33° to 57°) and very damp: Greenwich, Cochabamba.
10. Cool and moderately damp: Vienna, Melbourne, Toronto, Chicago.
11. Cool and dry: Tashkent, Simla, Cheyenne.
12. Cool and very dry: Yarkand, Denver.
13. Cold (32° or less) and very damp: Ben Nevis, Sagastyr, Godthaab.

14. Cold and moderately damp: Tomsk, Pike's Peak, Polaris House.

15. Cold and dry: (No example given).

16. Cold and very dry: Pamir.

Classification of Rainfall Systems.—The seasonal occurrence of rainfall has suggested a classification of the rainfall systems of the world into types. While these schemes are useful in climatological study, they are hardly to be considered as classifications of cli-

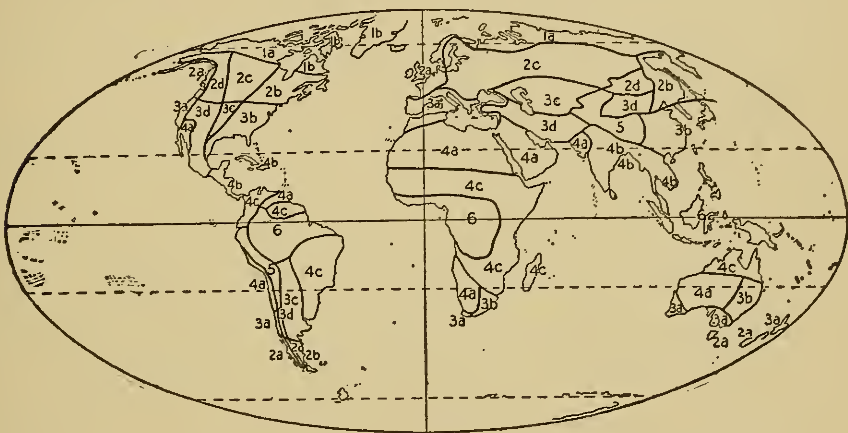

FIG. 18. HERBERTSON'S MAJOR NATURAL REGIONS

mate. Mühry [1] gave a rigid scheme of rainfall types in six belts for each hemisphere, these belts being divided by latitude lines; and Köppen has prepared a useful map of the hyetal regions of the world, based on the seasonal distribution of rainfall types.[2]

[1] A. Mühry: *Klimatographische Uebersicht der Erde,* Leipzig and Heidelberg, 1862, 741-744. Also: *Allgemeine geographische Meteorologie,* 1860, 145, and note 23, 199. Containing chart, as well as the scheme of rainfall types.

[2] See *Atlas of Meteorology,* Plate 19.

Herbertson's Natural Geographical Regions.—A scheme of "natural geographical regions" has been suggested by Herbertson,[1] the basis of classification being a certain unity of temperature, rainfall seasons, configuration and vegetation (Fig. 18).

The different types of natural regions recur in fairly systematic order on the different continents, being chiefly controlled by marine and continental influences, and each type, wherever found, has certain similar general relations to human life and development, as well as to animals and plants. The types are as follows:

1. Polar. (*a*) Lowlands (Tundra type); (*b*) Highlands (Ice-cap type).

2. The cool temperate regions. (*a*) Western margin (West European type); (*b*) Eastern margin (Quebec type); (*c*) Interior lowlands (Siberian type); (*d*) Interior mountain area (Altai type).

3. The warm temperate regions. (*a*) Western margin with winter rains (Mediterranean type); (*b*) The eastern margin, with summer rains (China type); (*c*) The interior lowlands (Turan type); (*d*) Plateau (Iran type).

4. (*a*) The west tropical deserts (Sahara type); (*b*) East tropical lands (Monsoon type); (*c*) Intertropical table-lands (Sudan type).

[1] A. J. Herbertson: "The Major Natural Regions: An Essay in Systematic Geography." *Geogr. Journ.* xxv., 1905, 300-309. A revised chart has been published in Herbertson's *The Senior Geography*, Oxford, 1907. (The Oxford Geographies, Vol. III.)

5. Lofty tropical or sub-tropical mountains (Tibetan type).

6. Equatorial lowlands (Amazon type).

Summary and Conclusions. The broad classification of climates into the three general groups of marine, continental, and mountain, with the subordinate divisions of desert, littoral, and monsoon, is convenient for purposes of summarising the interaction of the climatic elements under the controls of land, water, and altitude. But in any detailed study, some scheme of classification is needed in which similar climates in different parts of the world are grouped together, and in which their geographic distribution receives particular consideration. It is obvious from the preceding paragraphs that an almost infinite number of classifications might be proposed; for we may take as the basis of subdivision either the special conditions of one climatic element, as, for example, the same mean annual temperature, or mean annual range of temperature, or the same rainfall, or rainy seasons, or humidity, and so on. Or again, similar conditions of the combination of two or more elements of climate may be made the basis of classification. Or we may take a botanical, or a zoölogical basis. Of the classifications which have been proposed, special reference is here made to those of Supan, Köppen, and Herbertson. That of Supan, taken as a whole, gives a rational, simple, and satisfactory scheme of grouping, whose frequent use in climatic descriptions would tend toward system, sim-

plicity, and facility of comparison. It emphasises the essentials of each climate, and serves to impress these essentials upon the mind by means of the compact, well-considered summary which is given in the case of each province described. Obviously, no classification of climates which is at all complete can approach the simplicity of the ordinary classification of the zones.

Köppen's admirable scheme of subdividing climates, with the emphasis on the botanical side, is perhaps better adapted to the use of students of plant geography than of general climatology. But it has the great merit of recognising the existing differences of climate between east and west coasts, and between coasts and interiors. The co-ordination of districts of vegetation and of climate, which this scheme so strikingly emphasises, is a noteworthy fact in climatology. The subdivision could obviously be continued almost indefinitely.

Herbertson's classification of the natural geographical regions is, on the whole, not very unlike that adopted in Supan's climatic provinces, but is less complete. It is obvious that no scheme of subdivision of this kind can be regarded as being rigid or as satisfying all students of questions of distribution. Nevertheless, some general grouping of climatic regions with reference to similar features of temperature and rainfall and configuration, is a distinct help in most geographical studies. The larger types naturally recur on the several continents, in a fairly

systematic fashion. It results from this fact that there is a recurrence, in a large way, of somewhat similar conditions of life. This is a particularly helpful consideration in investigations of the economic and political history of mankind. The chief peculiarities of the important types can be readily learned; the special variations in individual areas may be investigated for each case by itself.

Ravenstein's hygrothermal types rest upon unsatisfactory data, and regions of very different climatic conditions are grouped together because they happen to have the same mean annual temperature and relative humidity.

CHAPTER IV

THE CHARACTERISTICS OF THE ZONES: I.—THE TROPICS

General: Climate and Weather—Temperature—The Seasons—Physiological Effects of Heat and Humidity—Pressure—Winds and Rainfall—Land and Sea Breezes—Thunderstorms—Cloudiness—Intensity of Skylight and Twilight—Climatic Subdivisions:—I. The Equatorial Belt.—II. Trade Wind Belts.—III. Monsoon Belts.—IV. Mountain Climate.

General: Climate and Weather. The so-called "torrid zone" has been variously bounded. Its limits have been set at the tropics (lat. 23½°); at the mean annual isotherms of 68°, which also correspond closely with the poleward extension of palms; and at the polar margins of the trade winds. The dominant characteristic of this great belt, embracing but a little less than one-half of the earth's surface, is the remarkable simplicity and uniformity of its climatic features. This simplicity is reflected in the striking regularity in the recurrence of the ordinary weather phenomena. The tropics lack the proverbial uncertainty and changeableness which characterise the weather of the higher latitudes. In the torrid zone, weather and climate are essentially synonymous terms. Periodic phenomena, depending upon the daily and annual march of the sun, are dominant. Non-periodic weather changes are wholly subordi-

nate. The succession of daily weather changes is even more regular, and the distribution of the climatic elements is even more uniform over the tropical oceans than over the lands. In special regions only, and at special seasons, is the regular sequence of weather temporarily interrupted by an occasional tropical cyclone. These cyclones, although comparatively infrequent, are notable features of the climate of the areas in which they occur. Generally bringing very heavy rains, and thus locally increasing the total annual precipitation by a considerable amount, they yet cause no marked temperature changes such as those which are the common accompaniments of extra-tropical cyclones. The devastation produced by one of these storms often affects the economic condition of the people in the district of its occurrence for many years.

Temperature. The sun is always well up in the sky. The length of day and night varies little. Hence the mean temperature is high, it is very uniform over the whole zone, and there is little variation during the year. The mean annual isotherm of 68° is a rational limit at the polar margins of the zone, and the mean annual isotherm of 80° encloses the greater portion of the land areas, as well as much of the tropical oceans. The isotherms are thus far apart. The warmest latitude circle for the year is not the equator, but latitude 10° north. The highest mean annual temperatures, shown by the isotherm of 85°, are in central Africa, in India, the north of

Australia and Central America, but, with the exception of the first, these areas are small. Massowah, on the Red Sea, has an annual mean of over 86°. The temperatures average highest where there is little rain, and not in the belt of heavy equatorial rains, where the clouds afford some protection from the sun's rays. In June, July, and August there are large districts in the south of Asia, and in northern Africa, with temperatures over 90°. Winds blowing out from these heated deserts are uncomfortably hot and dusty.

Over nearly all of the zone the mean range of temperature is less than 10°, and over much of it, especially the oceans, it is less than 5°. At Equatorville, in the interior of Africa, on the Congo, the mean annual range is only a little over 2°; at Iquitos (lat. 3.7° S.), in Peru, it is 4.3°. Even near the margins of the zone, where the seasonal differences are greatest, the ranges are less than 25°, as at Calcutta, Hong Kong, Rio de Janeiro and Khartum. The mean daily range is usually larger than the mean annual. Thus at Equatorville the former is about 14.5°. It has been well said that "night is the winter of the tropics." The differences between the maximum and minimum temperatures of the year near the equator are not much greater than the daily range. Over an area covering parts of the Pacific and Indian Oceans, from Arabia to the Caroline Islands and from Zanzibar to New Guinea, as well as on the Guiana coast,

the minimum temperatures do not normally fall below 68°, and over much of the torrid zone as a whole they do not fall below 59°. Towards the margins of the zone, however, the minima on the continents fall to, or even below, 32°. Maxima of 115°, and even over 120° (122°), occur over the deserts of northern Africa. A district where the mean maxima exceed 113° extends from the western Sahara to northwestern India, and over central Australia. Near the equator the maxima are therefore not as high as those in many so-called "temperate" climates. The greater portion of the torrid zone is a water surface, and marine conditions are therefore typical for most of it. These tropical oceans show remarkably small variations in temperature. The *Challenger* results showed a daily range of hardly 0.7° in the surface water temperature on the equator, and Schott determined the annual range as 4.1° on the equator; 4.3° at latitude 10°, and 6.5° at latitude 20°. It has been clearly pointed out by Hann that the uniform distribution of temperature throughout the year—the dominant feature of the tropics—results not only from (1) the small variation in insolation and in the length of the day; but also (2) from the great extent of the zone, which makes it impossible for cold winds from higher latitudes to penetrate into the lower latitudes; (3) the oblique course of the trades, which are well warmed on their indirect road towards the equator; (4) the slight nocturnal cooling, where the air

is damp and vapour is readily condensed; and (5) the great extent of the tropical oceans, which gives so much of the zone a marine climate.

The Seasons. In a true tropical climate, seasons, in the temperate zone sense, do not exist. The variations in temperature throughout the year are so slight that the seasons are not classified according to temperature, but depend on rainfall and the prevailing winds. The life of animals and plants in the tropics, and of man himself, is regulated very largely, in some cases almost wholly, by rainfall. Agriculture prospers, or fails, according to the sufficiency and punctual appearance of the rains. After a long dry season, when the rains come, there is an extraordinarily sudden awakening of the parched and dusty vegetation. Where, on the other hand, there is abundant moisture throughout the year, a tree may at the same time be carrying buds, blossoms, and ripe fruit. Vegetation under these conditions has been well called non-periodic. Although the tropical rainy season is characteristically associated with a vertical sun (*i. e.,* summer), that season is not necessarily the hottest time of the year. The temperature is usually somewhat lower under the clouds. The rainy season often goes by the name of winter for this reason, and also because the weather is dull. The time of the maximum temperature is also controlled by the rainy season. Towards the margins of the zone, with increasing annual ranges of temperature, seasons in the extra-tropical sense gradually appear.

Physiological Effects of Heat and Humidity. Tropical monotony of heat is associated with high relative humidity, except over deserts and in dry seasons. The air is therefore muggy and oppressive. The high temperatures are disagreeable and hard to bear. The "hot-house air" has an enervating effect. Energetic physical and mental action are often difficult, or even impossible. The tonic effect of a cold winter is lacking. The most humid districts in the tropics are the least desirable for persons coming from higher latitudes; the driest are the healthiest. The most energetic natives are the desert-dwellers. The monotonously enervating heat of the humid tropics weakens, so that man becomes sensitive to slight temperature changes. A fall of temperature to within a few degrees of 70° seems to some tropical natives almost unbearably cold, and certain African tribes sleep on clay banks heated inside by fires, although the mean temperature of the coldest month is over 70°. In drier climates such changes are more easily borne. The intensity of direct insolation, as well as of radiation from the earth's surface, may produce sunstroke and heat prostration. "Beware of the sun" is a good rule in the tropics.

Pressure. The uniform temperature distribution in the tropics involves uniform pressure distribution. Pressure gradients are weak. The annual fluctuations are slight, even on the continents. The diurnal variation of the barometer is so regular and so marked that, as von Humboldt said, the time of day can be

told within about fifteen minutes if the reading of the barometer be known. Even severe thunderstorms do not overcome the regular diurnal march of the pressure, but the approach of tropical cyclones can be foretold by the pressure changes.

Winds and Rainfall. Within the tropics, there are both heavy rains and large districts of very deficient precipitation. Along the barometric equator, where the pressure gradients are weakest, is the equatorial belt of calms, variable winds and rains—the doldrums. This belt, with its actively ascending, damp, hot air, offers exceptionally favourable conditions for abundant rainfall, and belongs among the rainiest regions of the world, averaging probably about one hundred inches. The rainfall is so heavy that the salinity of the surface waters of the oceans is actually less than in the latitudes of the trades. The sky is prevailingly cloudy, especially in the early afternoon hours; the air is hot and oppressive; heavy showers and thunderstorms are frequent, chiefly in the afternoon and evening—conditions not very unlike those which exist during certain spells of summer weather in the north temperate zone. There are the dense tropical forests of the Amazon and of equatorial Africa. There frost and drought need not be feared. This belt of calms and rains, of variable width and rather indefinite limits, shifts north and south of the equator after the sun. It is dreaded by seamen because sailing vessels are apt to have long delays in crossing it. The calm belt is generally

somewhat narrower than the belt of rains, the warm ascending air being carried north and south, and giving precipitation beyond the limits of the calm zone. In striking contrast are the easterly trade winds, blowing between the tropical high pressure belts and the equatorial belt of low pressure, and supplying to the doldrum belt a constant flow of warm air which already contains a large amount of water vapour, evaporated from the oceans by the trades, and needs only a moderate cooling in order to give abundant rainfall. Of great regularity, embracing about one-half of the earth's surface, and adding greatly to the uniformity of tropical climates, the trades have long been favourite sailing routes because of the steadiness of their winds, the infrequency of storms, the brightness of their skies, and the freshness of the air, all of which are in pleasing contrast with the muggy and oppressive calms of the doldrums. The most desirable house-sites in the tropics are very commonly on the top of some elevation, exposed to the trade wind. The trades are subject to many variations. Their northern and southern margins shift north and south after the sun; at certain seasons they are interrupted, often over wide areas near their equatorward margins, by the migrating belt of equatorial rains and by monsoons; near lands, they are often interfered with by land and sea breezes; in certain regions, they are invaded by violent cyclonic storms. The trades, except where they blow onto windward coasts, or over mountains, are natu-

rally drying winds, for they blow from higher to lower latitudes. Some facts seem to show that there is a descending component in the trades. They cause the deserts of northern and southern Africa, eastern Asia, Australia, and southern South America. Over the oceans, the only rains in the trade wind belts are in the form of passing showers.

The monsoons on the southern and eastern coasts of Asia are the best known winds of their class. In the northern summer, the south-west monsoon, warm and sultry, blows over the latitudes from about 10° north to and beyond the northern tropic, between Africa and the Philippines, giving rains over India, the East Indian Archipelago, and the east coasts of China. These winds reach a storm velocity over the Arabian sea. In winter, the south-east monsoon, the normal, cold-season, continental outflow from Asia, combined with the north-east trade, generally cool and dry, covers the same district, extending as far north as latitude 30°. Crossing the equator, these winds reach northern Australia, and the western islands of the South Pacific, as a north-west rainy monsoon, while this region in the opposite season has the normal south-east trade. Other monsoons are found in the Gulf of Guinea and in equatorial Africa. Wherever they occur, they control the seasonal changes.

The most important climatic phenomenon of the year in the tropics is the rainy season. Tropical rains are, in the main, summer rains, *i. e.,* they follow,

as a general rule, soon after the "vertical sun,"[1] the rainy season coming when the normal trade gives way to the equatorial belt of rains, or when the summer monsoon sets in. There are, however, many cases of a rainy season when the sun is low, especially on windward coasts in the trades. Tropical rains come usually in the form of heavy downpours and with a well-marked diurnal period, the maximum varying with the locality between noon and midnight. The conditions at Calcutta, as shown in the accompanying data, are fairly typical.[2]

DIURNAL DISTRIBUTION OF RAINFALL AT CALCUTTA.

12 P.M.—2 A.M.	50	12 M.—2 P.M.	111
2–4 A.M.	71	2–4 P.M	116
4–6 A.M.	65	4–6 P.M.	120
6–8 A.M.	71	6–8 P.M.	128
8–10 A.M.	58	8–10 P.M.	73
10 A.M.—12 M.	92	10 P.M.—12 P.M.	45

Local influences are, however, very important, and in many places night rainfall maxima are found.

The tropical rainy season is therefore not to be thought of as a period of continuous rains, falling steadily day and night for week after week. The mornings are often fine, with clean air, well washed by the rains of the preceding afternoon or night. Woeikof's detailed studies of tropical rainfalls, as a whole, lead him to the conclusion that (1) the intensity of tropical rains averages higher than in middle

[1] It will be remembered that at all places within the tropics the sun is vertical twice in the year.

[2] Seven year record; expressed in thousandths of the daily mean.

latitudes, but the difference is not great; (2) the heaviest short downpours have, so far as observation now goes, occurred in middle latitudes; (3) general, moderate rainfalls lasting continuously for many hours, which are common in the temperate zones, are known in many parts of the tropics and have even been given special names; (4) the heaviest daily rainfalls have been noted outside the tropics, as at Cherrapunji, for example; and (5) it is likely that the most intense rains in the tropics fall during large tropical cyclones.

Land and Sea Breezes. The sea breeze is an important climatic feature on many tropical coasts. With its regular occurrence, and its cool, clean air, it serves to make many districts habitable for white settlers, and has deservedly won the name of "the doctor." On not a few coasts, the sea breeze is a true prevailing wind. The location of dwellings is often determined by the exposure of a site to the sea breeze. For this reason, many native villages are put as near the sea as possible. The houses of well-to-do foreigners often occupy the healthiest and most desirable locations, where the sea breeze has a free entrance, while the poorer native classes live in the lower, less exposed and less desirable places. A social stratification is thus determined by the sea breeze.

Thunderstorms. Local thunderstorms are frequent in the humid portions of the tropics. They have a marked diurnal periodicity; find their best opportunity in the equatorial belt of weak pressure

gradients and high temperature, and are commonly associated with the rainy season, being most common at the beginning and end of the regular rains. In many places, thunderstorms occur daily throughout their season, with extraordinary regularity and great intensity. Lightning is, however, reported as very seldom doing any damage. Attention has been called to the fact that the frequent electrical discharges cause the rain water to be relatively rich in nitric acid. This condition, together with the carbon dioxide in the rain water and the high temperature of the same, promotes active and deep rock decomposition. In higher latitudes, where the ground may be frozen part of the year, and where the decomposing action of rain water is less, there is less of this effect. In northern India, hail-storms of great violence occur, and persons have been killed by them.

Cloudiness. Taken as a whole, the tropics are not favoured with such clear skies as is often supposed. Cloudiness varies about as does the rainfall. The maximum is in the equatorial belt of calms and rains, where the sky is always more or less cloudy. The minimum is in the trade latitudes, where fair skies as a whole prevail.[1] The equatorial cloud belt moves north and south after the sun. Wholly clear days are very rare in the tropics generally, especially near

[1] Supan, *Grundzüge der Physischen Erdkunde*, 3d ed., 1903, Fig. 13, page 53, gives a diagram showing the distribution of rainfall and cloudiness (also of other elements) according to latitude.

the equator, and during the rainy season heavy clouds usually cover the sky.

Tropical clouds and rainfall, as a whole, repeat, in an exaggerated form, the summer conditions of much of the north temperate zone. Broken skies; cumulus and cumulo-nimbus clouds; heavy showers or thunderstorms—these usually characterise the rainy season. Skies clear, or flecked with scattered small cumuli, are typical of the dry season. Wholly overcast, dull days, such as are common in the winter of the temperate zone, occur frequently only on tropical coasts in the vicinity of cold ocean currents, as in Peru and on parts of the west coast of Africa. In these same regions ocean fogs are common.

Intensity of Skylight and Twilight. The intensity of the light from tropical skies by day is trying, even almost unbearable, to newcomers. The intense insolation, together with the reflection from the ground, increases the general dazzling glare under a tropical sun, necessitating protection of some sort. The far-famed deep blue of the tropical sky is much exaggerated. During much of the time, smoke from forest and prairie fires (in the dry season); dust (in deserts), and water vapour give the sky a pale, whitish appearance. In the heart of the trade wind belts at sea, the sky is much more of a deep blue. The beauties of tropical sunrise and sunset, and of the tropical night, have, however, not been overrated. Twilight within the tropics is shorter than in higher latitudes, but the coming on of night is less sudden

than is generally assumed. Pechuel-Lösche and others have shown that it is possible, on the Loango coast, to read ordinary print twenty to thirty minutes after sunset.

Climatic Subdivisions. The rational basis for a classification of the larger climatic provinces of the torrid zone is found in the general wind systems and in their control over rainfall. Following this scheme there are these subdivisions: I. The equatorial belt; II. The trade wind belts; III. The monsoon belts. In each of these subdivisions there are modifications, due to ocean and continental influences. In general both seasonal and diurnal phenomena and changes are more marked in continental interiors than on the oceans, islands, and windward coasts. Further, the effect of altitude is so important that another subdivision should be added to include IV. Mountain climates.

I. *The Equatorial Belt.* Within a few degrees of the equator, and when not interfered with by other controls, the annual curve of temperature has two maxima following the two zenithal positions of the sun, and two minima at about the time of the solstices. This, which is known as the *equatorial* type of annual march of temperature, is illustrated in the data and curves for the interior of Africa, Batavia, and Jaluit. (Fig. 19).

The greatest range is shown in the curve for the interior of Africa; the curve for Batavia illustrates insular conditions with less range; and the oceanic type,

for Jaluit, Marshall Islands, gives the least range. At Jaluit, the daily maxima for the entire year are between 88° and 91.5° and the daily minima between 75° and 77°. This double maximum is not a universal phenomenon, there being many cases where but a single maximum occurs, as will be seen later.

TABLE OF MEAN MONTHLY TEMPERATURES FOR SELECTED TROPICAL STATIONS [1]

	I. Equatorial Type			II. Tropical Type				
	Continental	Insular	Marine	Continental		Monsoon	Insular	
	Africa interior	Batavia	Jaluit, Marshall Islands	Wadi Halfa	Alice Springs	Nagpur	Honolulu	Jamestown
Lat.	8.1° N.	6° 11′ S.	5° 55′ N.	21° 53′ N.	23° 38′ S.	21° 9′ N.	21° 18′ N.	15° 55′ S.
Long.	23.6° E.	106° 50′ E.	169° 40′ E.	31° 20′ E.	133° 37′ E.	79° 11′ E.	157° 50′ N.	5° 43′ W.
Altitude	1837 ft.	23 ft.	10 ft.	426 ft.	1926 ft.	1093 ft.	49 ft.	39 ft.
Jan.	73.4°	77.5°	80.8°	61.3°	85.6°	68.2°	70.0°	74.7°
Feb.	77.2°	77.7°	81.0°	66.6°	83.3°	73.8°	70.3°	75.9°
Mar.	83.8°	78.4°	80.6°	73.0°	77.9°	83.7°	70.9°	73.6°
April	85.3°	79.3°	80.4°	81.0°	68.5°	90.3°	72.9°	75.0°
May	83.7°.	79.5°	80.4°	87.1°	60.6°	94.3°	74.3°	68.9°
June	81.5°	78.8°	80.2°	91.4°	54.0°	85.6°	76.1°	70.5°
July	78.4°	78.3°	80.2°	93.4°	51.8°	80.1°	77.2°	71.8°
Aug.	75.7°	78.6°	80.4°	91.6°	59.4°	80.2°	77.5°	69.4°
Sept.	77.7°	79.3°	80.4°	87.1°	66.6°	80.4°	77.2°	67.6°
Oct.	78.1°	79.5°	80.8°	83.1°	73.4°	78.6°	76.5°	65.7°
Nov.	75.7°	79.0°	80.8°	71.4°	79.7°	72.3°	73.8°	67.8°
Dec.	72.9°	78.1°	80.6°	64.8°	82.8°	66.7°	71.4°	71.8°
Mean	78.6°	78.8°	80.6°	79.3°	70.3°	79.5°	73.9°	71.1°
Range	12.4°	2°	0.8°	32.1°	33.8°	27.6°	7.5	10.2°

As the belt of rains swings back and forth across the equator after the sun, there should be two rainy seasons with the sun vertical, and two dry seasons when the sun is farthest from the zenith, and while

[1] Given to nearest tenth of a degree Fahr.

the trades blow. These conditions prevail on the equator, and as far north and south of the equator (about 10°–12°) as sufficient time elapses between the two zenithal positions of the sun for the two rainy

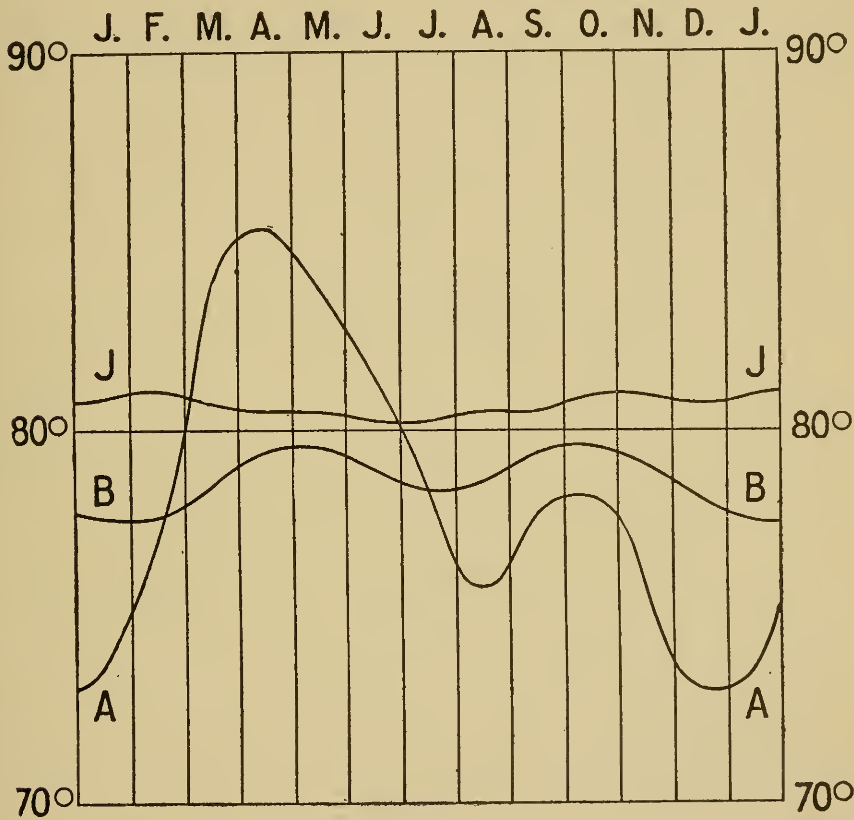

Fig. 19. Annual March of Temperature: Equatorial Type.
A: Africa, interior. B: Batavia. J: Jaluit, Marshall Islands.

seasons to be distinguished from one another. In this belt, under normal conditions, there is, therefore, no dry season of any considerable duration. The double rainy season is clearly seen in equatorial

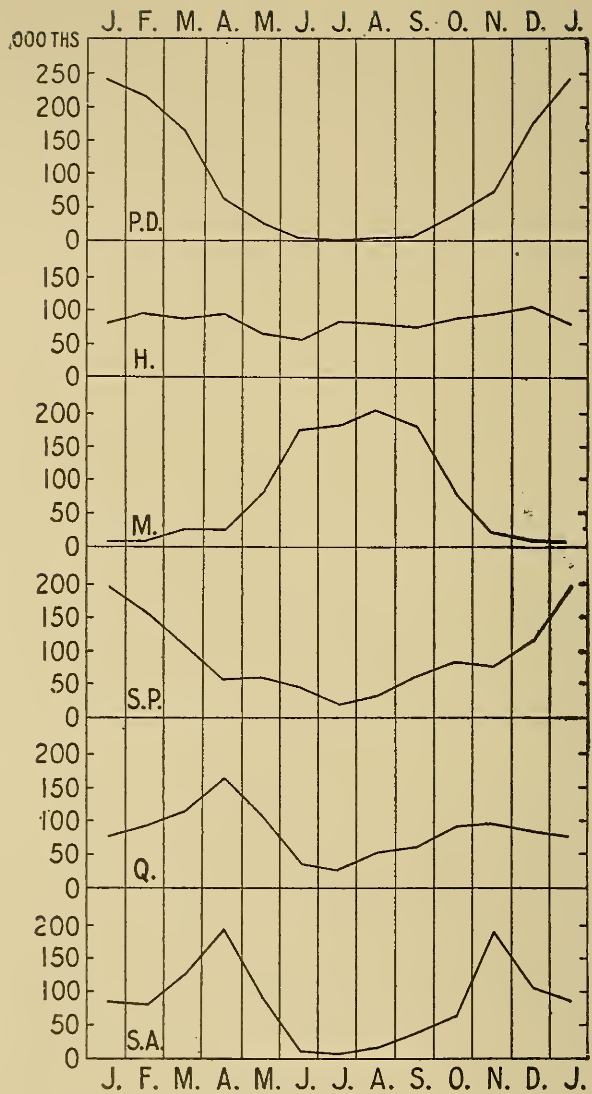

Fig. 20. Annual March of Rainfall in the Tropics

S. A: South Africa. Q: Quito. S. P: São Paulo. M: Mexico. H: Hilo. P. D: Port Darwin.

Africa and in parts of equatorial South America. The maxima lag somewhat behind the vertical sun, coming in April and November, and are unsymmetrically developed, the first maximum being the principal one. The minima are also unsymmetrically developed, and the so-called "dry seasons" are seldom wholly rainless. In this equatorial belt, the annual range of rainfall is generally below 20%; in the western portion of the Malay Archipelago and on the upper Amazon, it is below 10%. In these latitudes, therefore, the distribution of rainfall is not unlike that in extra-tropical latitudes which are under the marine regime of rainfall, there being precipitation at all seasons.

This rainfall type with double maxima and minima has been called the *equatorial* type, and is illustrated in the following data and in the curves for south Africa and Quito. (Fig. 20).

The mean annual rainfall at Quito is 42.12 inches. These double rainy and dry seasons are easily modified by other conditions, as by the monsoons of the Indo-Australian area, for example, so there is no rigid belt of *equatorial rains* extending around the world. In South America, east of the Andes, the distinction between rainy and dry seasons is often much confused. In this equatorial belt, the cloudiness is high throughout the year, averaging .7 to .8, with a relatively small annual period. The data and curve following are fairly typical, but the annual period varies greatly under local controls. (Fig. 21).

TABLE SHOWING MONTHLY DISTRIBUTION OF RAINFALL FOR SELECTED TROPICAL STATIONS [1]

	Tropics					
	Double Rainy Season Equatorial		Single Rainy Season			
			Margin of Tropics		Trade Rains	Monsoon Rains
			Southern	Northern		
	Southern Africa	Quito	São Paulo	Mexico	Hilo	Port Darwin
Latitude	6° S.	Equator	23.5° S.	19.4° N.	19.7° N.	12.5° S.
Jan.	86	77	195	7	79	241
Feb.	80	92	156	9	94	215
March	123	115	103	26	86	166
April	195	165	58	26	94	61
May	91	109	60	85	66	23
June	10	35	46	174	55	1
July	7	25	19	180	82	0
Aug.	17	52	31	207	81	2
Sept.	37	60	60	179	73	5
Oct.	61	91	82	79	88	38
Nov.	188	94	74	20	95	72
Dec.	105	85	116	8	107	176

TABLE SHOWING MONTHLY DISTRIBUTION OF CLOUDINESS IN AN EQUATORIAL CLIMATE. (CAMEROONS; GABOON. LAT. 3° N., WEST AFRICA.)

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov	Dec.	Year
5.4	6.3	7.0	7.2	7.4	7.7	8.9	8.6	8.4	8.0	7.4	6.6	7.4

At greater distances from the equator than about 10° or 12°, the sun is still vertical twice a year within the tropics, but the interval between these two dates is so short that the two rainy seasons merge into one, in summer, and there is also but one dry season, in

[1] The figures in this table are thousandths of the mean annual rainfall. In the first column of the table, the average of a considerable number of stations is given.

winter. This is the so-called *tropical* type of rainfall,[1] and is found where the trade belts are encroached upon by the equatorial rains during the migration of these rains into each hemisphere. It is illustrated in

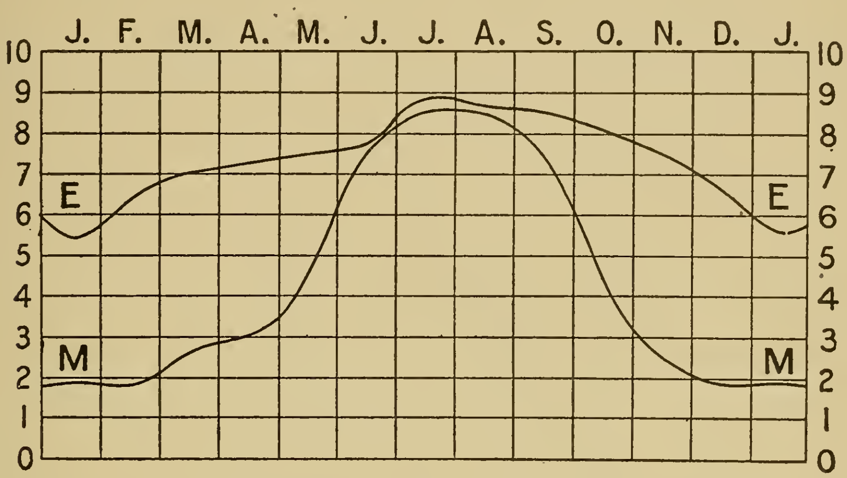

FIG. 21. ANNUAL MARCH OF CLOUDINESS IN THE TROPICS
E: Equatorial type. M: Monsoon type

the data and curves for São Paulo, Brazil, and for the city of Mexico (see rainfall table above and Fig. 20). The mean annual rainfall at São Paulo is 54.13 inches, and at Mexico 22.99 inches.

The districts of tropical rains of this type lie along the equatorial margins of the torrid zone, outside of the latitudes of the *equatorial* type of rainfall. The rainy season becomes shorter with increasing distance from the equator. The weather of the opposite seasons is strongly contrasted. The single dry season lasts longer than either dry season in the equatorial

[1] Supan calls it the *marginal* type of the tropics.

belt, reaching eight months in typical cases, with the wet season lasting four months. The lowlands often become dry and parched during the long, dry trade wind season (winter), and vegetation withers away, while grass and flowers grow in great abundance and all life takes on new activity during the time when the equatorial rainy belt, with its calms, variable winds, and heavy rains, is over them (summer). The Sudan lies between the Sahara and the equatorial forests of Africa. It receives rains, and its vegetation grows actively, when the doldrum belt is north of the equator (May–August). But when the trades blow (December–March), the ground is parched and dusty. The Venezuelan llanos have a dry season in the northern winter, when the trade blows. The rains come in May–October. The campos of Brazil, south of the equator, have their rains in October–April, and are dry the remainder of the year. The Nile overflow results from the rainfall on the mountains of Abyssinia during the northward migration of the belt of equatorial rains.

Simple *tropical* rainfalls, as shown in the above curves, are typical of large areas, but they are not infrequently complicated by association with trade or monsoon rains, as in the West Indies, Central America, and India. The true doldrum rains may come along the polar margin of the equatorial low-pressure belt, when this belt is moving equatorward, followed by the trades.

The so-called tropical type of temperature variation,

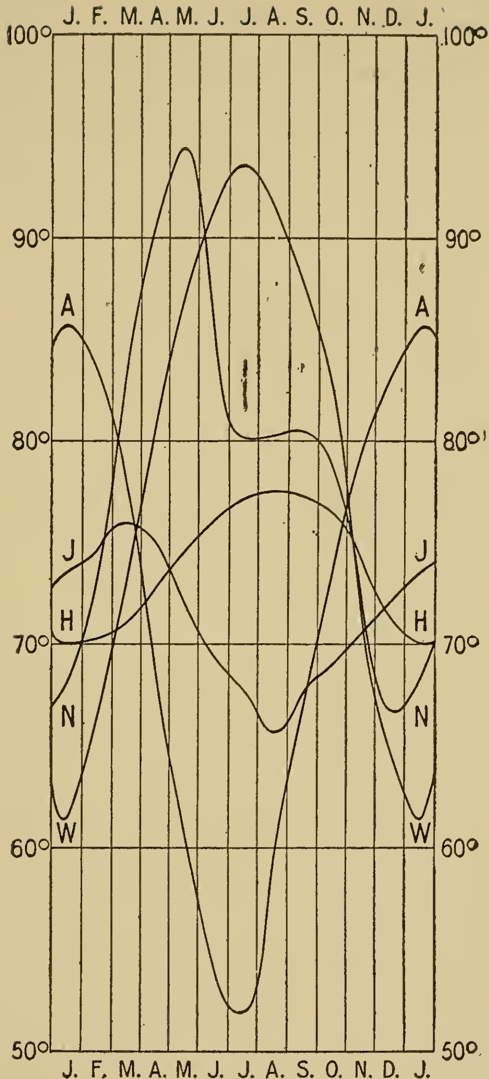

FIG. 22. ANNUAL MARCH OF TEMPERATURE: TROPICAL TYPE

W: Wadi Halfa. N: Nagpur. A: Alice Springs. H: Honolulu. J: Jamestown, St. Helena

with one maximum and one minimum, is illustrated in the data given in the table on page 90, and in the accompanying curves for Wadi Halfa, in Upper Egypt; Alice Springs, Australia; Nagpur, India; Honolulu, Hawaii, and Jamestown, St. Helena. The effect of the rainy season is often shown in a displacement of the time of maximum temperature to an earlier month than the usual one. During the rains, the temperature is apt to remain constant, as in the case of Nagpur, and of other stations in India, Mexico, and the interior of Senegambia. This type of temperature curve is characteristic of most of the tropics outside of the latitudes reached by the equatorial belt.

II. *Trade Wind Belts.* The trade belts near sea-level are characterised by fair weather, steady winds, infrequent light rains or even an almost complete absence of rain; very regular, although slight, annual and diurnal ranges of temperature, and a constancy and regularity of weather which is more truly "temperate" than that of most of the so-called temperate zone. The climate of the ocean areas in the trade wind belts is indeed the simplest and most equable in the world, the greatest extremes—and even these are moderate—being found to leeward of the larger lands, where the continental conditions are carried offshore by the prevailing winds. On the lowlands swept over by the trades, beyond the polar limits of the equatorial rain belt (roughly between lats. 20° and 30°), are most of the great deserts of the

world. These deserts extend directly to the water's edge on the leeward, western coasts of Australia, south Africa, and South America. In the two latter regions, the desert conditions are further helped by the presence of cold ocean currents offshore. Because of their great extent, these trade wind deserts constitute one of the most important climatic districts in the world.

The ranges and extremes of temperature are much greater over the deserts, especially the continental interiors, than over the oceans of the trade wind belts. Minima of 32° or less occur during clear, quiet nights, and daily ranges of over 50° are common. The midsummer mean temperature rises above 90°, with noon maxima of 110°, or more, in the non-cloudy, dry air of a desert day. The days, with high, dry winds, carrying dust and sand, with extreme heat, accentuated by the absence of vegetation, are disagreeable or even dangerous to life; but the calmer nights, with active radiation under clear skies, are much more comfortable. The nocturnal temperatures are even not seldom too low for comfort in the cooler season, when thin sheets of ice may form. Under the strong insolation by day and the quick cooling by night, rocks in the deserts split and break up. On the whole, however, man is less susceptible to the larger temperature ranges in tropical deserts than to the smaller ones in the equatorial belt, because of the lower relative humidity in the former case. In the trade wind deserts, as in other arid regions, man is nomadic.

While the trades are drying winds as long as they blow strong over the oceans, or over lowlands, they contain a large amount of water vapour, and readily become rainy if they are cooled during an ascent over a mountain or highland. Hence the windward (eastern) sides of mountains or bold coasts in the trade wind belts are well watered, while the leeward sides, or interiors, are dry. Mountainous islands in the trades, like the Hawaiian Islands, many of the East and West Indies, the Philippines, Borneo, Ceylon, Madagascar, Teneriffe, etc., show marked divergences of this sort. The eastern coasts of Guiana, Central America, south-eastern Brazil, south-eastern Africa, and eastern Australia are well watered, while the interiors are very dry in the two last-named countries. The eastern highland of Australia constitutes a more effective barrier than that in south Africa; hence the Australian interior has a more extended desert. South America in the south-east trade belt is not well enclosed on the east, and the most arid portion is an interior district near the eastern base of the Andes, where the land is low. Even far inland, the Andes again provoke precipitation along their eastern base, and the narrow Pacific coastal strip, to leeward of the Andes, is a very pronounced desert from the equator to about lat. 30° S. The cold ocean waters, with prevailing southerly (drying) winds alongshore, are additional factors in causing this aridity. The Peruvian climatic province is abnormally cool. Highlands in the trade belts are therefore

moist on their windward slopes—even in deserts, mountains provoke local rainfall, tree growth, and local streams—and becomes oases of luxuriant plant growth, while close at hand, on the leeward sides, dry savannas or deserts may be found. The damp, rainy and forested windward (N.E. trade) side of Central America was, from the earliest days of European occupation, left to the natives, while the centre of civilisation was naturally established on the more open and sunny south-western side.

The rainfall associated with the conditions just described is known as the *trade* type. These rains have a maximum in winter, when the trades are most active, this being a departure from the general rule of summer rains in the tropics. In cases where the trade blows steadily throughout the year against mountains or bold coasts, as on the Atlantic coast of Central America, there is no really dry season. The data and curve for Hilo (mean annual rainfall 145.24 inches), on the windward side of the Hawaiian Islands, show typical conditions (see Fig. 20). The *tropical* rains are convectional, and therefore prefer the warm season; the trade rains are orographic, and have a winter maximum.

The *trade* type of rainfall is often much complicated by the combination with it of the *tropical* type and of the *monsoon* type (see next paragraph). Zanzibar, for example, has its principal maximum of rainfall in April, which is pure *tropical*, and has a secondary maximum in December, which is *trade*.

Again, on the lee of highlands which receive a winter maximum on their windward slopes, summer rains may occur at the time when the trade is weakest, and the otherwise long dry season is interrupted by scattering showers. In the Malay archipelago, there are complications of equatorial and trade rains; likewise in the West Indies. Trade rains often have a tendency to give precipitation both day and night, while torrid zone rains generally prefer the day.

III. *Monsoon Belts.* In a typical monsoon region, such as that of India, eastern Asia, and the adjacent islands, the rains follow the vertical sun, and therefore have a simple annual period much like that of the *tropical* type above described, the dry season coming when the sun is lowest (winter). This monsoon type of rainfall is well illustrated in the data and curve for Port Darwin (mean annual rainfall 62.72 inches), in Australia. This summer monsoon rainfall results from the inflow of a large body of warm, moist air from the sea on to a land area; a consequent retardation of the velocity of the air currents, as the result of friction, and an ascent of the air, the rainfall being particularly heavy where the winds have to climb over high lands. Thus, in India, the precipitation is heaviest at the head of the Bay of Bengal, where Cherrapunji, at the height of 4455 feet in the Khasi Hills, has a mean annual rainfall of between 400 and 500 inches; along the southern base of the Himalayas (60 to 160 inches); on the bold western coast of the peninsula (80 to 120 inches and

over), and on the mountains of Burma (up to 160 inches). In the rain-shadow of the Western Ghats, the Deccan often suffers from drought and famine unless the monsoon rains are abundant and well distributed, and the decreasing rainfall up the Ganges valley leaves the Indus plain with a deficiency (less than five inches). The prevailing direction of the rainy monsoon wind in India is south-west; on the Pacific coast of Asia, south-east. This monsoon district is very large, including the Indian Ocean, Arabian Sea, Bay of Bengal, and adjoining continental areas; the Pacific coast of China, the Yellow and Japan seas, and numerous islands from Borneo to Sakhalin on the north and to the Ladrone Islands on the east. Where the seasons are clearly defined in India, they are three in number: a cool, dry season (winter) when northerly trade winds prevail, and when there is little or no rainfall except in the northern provinces, where moderate cyclonic storms occasionally occur; a wet season, sultry and oppressive, with the inflowing south-west monsoon of summer; and a hot, dry season before the beginning of the rains. The beginning of the monsoon rains usually comes suddenly ("burst"), with heavy thunderstorms. A typical temperature curve for a monsoon district is that for Nagpur, in the Indian Deccan (see Fig. 22), and a typical cloudiness curve is given in Fig. 21, the maximum coming near the time of the vertical sun, in the rainy season, and the minimum in the dry season.

TABLE SHOWING MONTHLY DISTRIBUTION OF CLOUDINESS IN A MONSOON CLIMATE (BENGAL, LAT. 23.5° N.).[1]

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1.9	1.8	2.6	3.0	4.5	7.5	8.5	8.4	7.5	4.3	2.5	1.8	4.5

In the Australian monsoon region, which reaches across New Guinea and the Sunda Islands, and west of Australia, in the Indian Ocean, over latitudes 0°–10° S., the monsoon rains come with north-west winds in the period between November and March or April. The northern portion of Australia is thus watered by zenithal summer rains, and the southern portions of Sumatra, Borneo, and Java are also under the influence of this north-west monsoon. The essential features of the whole Indo-Australian monsoon belt, therefore, are a fairly uniform distribution and small annual range of temperature; and well-marked periodic rains, coming with north-west or south-west winds according to the hemisphere.

The general rule that eastern coasts in the tropics are the rainiest finds exceptions in the case of the rainy western coasts in India and other districts with similar rains. On the coast of the Gulf of Guinea, for example, there is a small rainy monsoon area during the summer; heavy rains fall on the seaward slopes of the Cameroon Mts. Not far inland, Baliburg shows a double maximum of the equatorial type. Gorée, lat. 15° N., on the coast of Senegambia, gives a fine example of a rainy (summer) and a dry (winter) monsoon. A case of a special kind is the Somali

[1] Five stations.

coast, which trends N.E–S.W., and is therefore parallel with both monsoons. Hence at no season can it become very rainy, and mean annual rainfalls of 40 inches are not recorded until the coast takes a turn to the south, at Mombasa.

Numerous combinations of equatorial, trade and monsoon rainfalls are found, often creating great complexity. In the case of Port Darwin, the station is near enough to the equator to have two rainy seasons (*equatorial* type) when the sun is vertical, as is frequently the case in the West Indies and Central America in the same latitude. The rainiest month, however, is January, between the two times of vertical sun, but during the height of the monsoon, there being a rainy season of four months and a dry season of eight months. The monsoon thus interferes with the typical occurrence of equatorial rains. It is also true that the dry season in monsoon districts is drier than the two dry seasons of the equatorial type. Batavia, on the island of Java, has simple monsoon rains. Buitenzorg, on the same island, has a monsoon maximum in January, two months before the sun is vertical for the first time, and it has a regular tropical maximum of rainfall in October, following the second zenithal position of the sun. The north coast of Ceram, in the Moluccas, has north-west summer monsoon rains, with a maximum in February, while the south coast has winter rains, with the southeast trade. The rainy and dry seasons thus come under different conditions and at opposite times on

the two coasts. These two sets of conditions are often very close together, with a divide between them. On the island of Hawaii, Hilo, on the east side, is exposed to the north-east trade and has a winter maximum of rainfall. Kailua, on the lee side, has about one-third as much rainfall, with a summer maximum. The islands of the East Indian archipelago furnish many examples of such curious complications. The eastern coast of Madagascar has south-east trade winds fairly uniformly through the year, while the interior and west coast have a summer maximum—the normal tropical rainfall season.

IV. *Mountain Climate.* Within the tropics, altitude is chiefly important because of its effect in tempering the heat of the lowlands, especially at night. If tropical mountains are high enough, they carry snow the year around, even on the equator, and the zones of vegetation may range from the densest tropical forest at their base to the snow on their summits. The highlands and mountains within the tropics are thus often sharply contrasted with the lowlands, and offer more agreeable and more healthful conditions for white settlement. They are therefore often sought out by residents from colder latitudes as the most attractive resorts. In India, the hill stations are crowded during the hot months by civilian and military officials, and it has been well said that India is ruled from 7,000 feet above sea-level. The climate of many tropical plateaus and mountains has the reputation of being a "perpetual spring."

Thus, on the interior plateau of the tropical Cordilleras of South America, and on the central plateau of tropical Africa, the heat is tempered by the altitude, while the lowlands and coasts are very hot. The rainfall on tropical mountains and highlands often differs considerably in amount from that on the lowlands, and other features common to mountain climates the world over are also noted. But the main emphasis is rightly laid upon the temperature.

CHAPTER V

THE CHARACTERISTICS OF THE ZONES: II.—THE TEMPERATE ZONES

General: "Temperate" Zones—Temperature—Pressure and Winds—Rainfall—Humidity and Cloudiness—Seasons: Their Effects on Man—Weather—Climatic Subdivisions—South Temperate Zone—Sub-tropical Belts: Mediterranean Climates—North Temperate Zone: Western Coasts—Interiors—Eastern Coasts—Mountain Climates.

General: "Temperate" Zones. The so-called "temperate" zones occupy about one-half of the earth's surface. As a whole, they are *temperate* only in that their mean temperatures and their physiological effects are intermediate between those of the tropics and those of the polar zones. The modifications of solar climate which result from the distribution and influence of land and water are greatest in the temperate zones. The north temperate zone includes the greatest known extremes of temperature. If the use of the word "temperate" were not so firmly established it would be well to change the name to *intermediate,* or to *middle.*[1]

[1] North-middle and south-middle would then distinguish the zones in the two hemispheres. (See W. M. Davis: *The Temperate Zones, Journ. Geogr.*, vol. i, 1897, pp. 139-143.) "Temperate" does, however, apply fairly well to the south temperate zone.

A marked changeableness of the weather is a striking characteristic of these zones. Apparently irregular and haphazard, these continual weather changes nevertheless run through a fairly systematic series, although they are essentially non-periodic. Climate and weather are by no means synonymous over most of the extra-tropical latitudes.

Temperature. The mean annual temperatures at the margins of the north temperate zone differ by more than 70°. The ranges between the mean temperatures of hottest and coldest months reach 120° at their maximum in north-eastern Siberia, and 80° in North America. A January mean of —60° and a July mean of 95°, and maxima of over 120° and minima of —90°, occur in the same zone. In the districts of lowest winter minima, the mean summer temperatures exceed 85°, and in portions of the districts of highest mean summer maxima, the mean winter minima fall below 32°. Such great ranges characterise the extreme land climates. Under the mild influence of the oceans, the windward west coasts have much smaller ranges than the interiors; the seasonal differences increase inland. The annual ranges in the middle and higher latitudes exceed the diurnal, the conditions in much of the torrid zone being exactly reversed. Over much of the oceans of the temperate zones the annual range is less than 10°. In the south temperate zone there are no extreme ranges, the maxima, slightly over 30°, being near the margin of the zone in the interior of South America, south

Africa, and Australia. In these same localities, the diurnal ranges, however, rival those of the north temperate zone.

The north-eastern Atlantic ocean and north-western Europe are about 35° too warm for their latitude in January, while north-eastern Siberia is 30° too cold. The lands north of Hudson's Bay are 25° too cold, and the waters of the Alaskan Bay 20° too warm. In July, and in the southern hemisphere, the anomalies are small. The lands which are the centre of civilisation in Europe average too warm for their latitudes. These lands are the most truly "temperate" portion of the north temperate zone. The northwest coast of North America is much the same. The diurnal variability of temperature is greater in the north temperate zone than elsewhere in the world, and the same month may differ greatly in its character in different years. One winter in higher latitudes may have much snow, and temperatures below normal; the next may give much rain instead of snow, and the ground remain unfrozen. One summer may be very favourable for crops; the next may give a poor harvest.

From the point of view of temperature, these zones may be considered in three divisions: (1) the subtropical, (2) the "temperate" latitudes, and (3) the sub-polar. The annual temperature curve has one maximum and one minimum. In the continental type, the times of maximum and minimum are about one month behind the maximum and minimum in-

solation dates. In the marine type, the retardation may amount to nearly two months. Coasts and islands have a tendency to a cool spring and warm autumn; continents, to similar temperatures in both spring and fall.

Pressure and Winds. The prevailing winds are the "westerlies," which occupy about as much of the earth's surface as do the easterly trades. The westerlies are, however, much less regular than the trades. They vary greatly in velocity in different regions and in different seasons, from a light wind to a gale of fifty or more miles an hour. They are stronger in winter than in summer. They are much interfered with, especially in the higher northern latitudes, by seasonal changes of temperature and pressure over the continents, whereby the latter establish, more or less successfully, a system of obliquely outflowing winds in winter and of obliquely inflowing winds in summer. On the eastern coast of Asia there is a complete reversal in wind direction at the opposite seasons, but usually the seasonal shift is much less than 180°. In summer, when the lands have low pressure, the northern oceans are dominated by great oval areas of high pressure, with outflowing spiral eddies, while in winter, when the northern lands have high pressure, the northern portions of the oceans develop cyclonic systems of inflowing winds over their warm waters. All these great continental and oceanic systems of spiraling winds are important climatic controls.

The westerlies are also much confused and interrupted by storms. Hence their designation of *stormy westerlies.* A constant succession of cyclones, and the accompanying anticyclones, travelling along with the prevailing westerlies, causes the latter very frequently to change direction in order to become part of a cyclonic or an anticyclonic whirl. In these storms, velocities of eighty or more miles an hour may be reached at sea. So common are such interruptions that the prevailing westerly wind direction is often difficult to discern without careful observation. Cyclonic storms are most numerous and best developed in winter. The irregular pressure changes usually wholly mask the faint diurnal variation of the barometer which is so characteristic of the tropics, and which becomes less and less marked with increasing latitude. Although greatly interfered with near sea-level by continental changes of pressure, by cyclonic and anticyclonic whirls, and by local inequalities of the surface, the eastward movement of the atmosphere remains very constant aloft. The drift of the higher clouds, and wind observations on mountains, show clearly that the upper currents blow with great steadiness from westerly points, the departures being temporary, and under the control of passing cyclones or anticyclones. The south temperate zone is chiefly water. Hence the westerlies are but little distorted by continental effects. They are strong and steady, and almost as regular as the trades. "Roaring forties" is a well-known designa-

tion for the southern middle latitudes, and between latitudes 40° and 60° S. the "brave west winds" blow with a constancy and a velocity found in the northern hemisphere only on the oceans, and then in a modified form. Storms, frequent and severe, characterise these southern hemisphere westerlies, and easterly wind directions are temporarily noted during their passage. Voyages to the west around Cape Horn against head gales, and in cold, wet weather, are much dreaded. South of Africa and Australia, also, the westerlies are remarkably steady and strong. The winter in these latitudes is stormier than the summer, but the seasonal difference is less than that north of the equator.

Between trades and westerlies lies a debatable belt of high pressure, shifting seasonally. Within it, stormy westerlies and drying trades alternately hold sway. It is the sub-tropical belt, a favoured climatic region, where invalids seek health, and an escape from the rigors of a cold winter is found by many who have time and means to leave their northern homes.

Rainfall. Rainfall is fairly abundant over the oceans, where evaporation is large, and also over a considerable part of the lands (30–80 inches, and more). It comes chiefly in connection with the usual cyclonic storms, or in thunderstorms, but altitude often serves locally to increase this precipitation. So great are the differences, geographic and periodic, in rainfall, produced by differences in temperature, topography, cyclonic conditions, etc., that none but

the most general rules can be laid down. The equatorward margin of the temperate zone rains is clearly defined on the west coasts, at the points where the coast deserts are replaced by belts of light or moderate rainfall. Bold west coasts, on the polar side of lat. 40°, are very rainy, having 100 inches and more a year in the most favourable situations. The hearts of the continents, far from the sea, and especially when well enclosed by mountains, or when blown over by cool ocean winds which warm in crossing the land, have light rainfall (less than 10–20 inches). East coasts, receiving rain from moist winds blowing in from the adjacent oceans as monsoons, or in front of cyclonic storms, are wetter than interiors, but drier than west coasts. Winter is the season of maximum rainfall over oceans, islands, and west coasts, for the westerlies are then most active, cyclonic storms are then most numerous and best developed, and the cold lands chill the inflowing damp air. At this season, however, the low temperatures, high pressures, and tendency to outflowing winds over the continents are unfavourable to rainfall, and the interior land areas, as a rule, then have their minimum. The warmer months bring the maximum rainfall over the continents. Then conditions are favourable for inflowing damp winds from the adjacent oceans; there is the best opportunity for convection; thunder-showers readily develop on the hot afternoons; the capacity of the air for water vapour is greatest. Continents, from equator to higher latitudes, thus have a tend-

ency to maximum rainfall in the warm season; summer rains, as a whole, predominate over the lands. The marine type of rainfall, with a winter maximum, extends in over the western borders of the continents, and is also found in the winter rainfall of the subtropical belts. These winter rains are in some respects like the winter rains on windward coasts in the trades. Coastal lands reached by them are well watered, and droughts need not be feared. Rainfalls are heaviest along the tracks of most frequent cyclonic storms.

For continental stations, the typical daily march of rainfall is shown in the accompanying data for Berlin and New York.

DAILY MARCH OF RAINFALL (THOUSANDTHS OF THE DAILY MEAN).

I. *Continental Type.*

Hours.	Berlin.	New York.
12 P.M.—2 A.M.	76	79
2–4	83	85
4–6	74	79
6–8	69	80
8–10	62	74
10–Noon	68	81
Noon—2 P.M.	85	83
2–4	105	95
4–6	104	91
6–8	113	90
8–10	83	85
10–12 P.M	78	78

The chief maximum is in the afternoon, and the secondary maximum comes in the night or early morning. The chief minimum comes between 10 A.M. and 2 P.M. Coast stations generally have a night

maximum, and a minimum between 10 A.M. and 4 P.M., as illustrated in the following data for Valentia.

DAILY MARCH OF RAINFALL AT VALENTIA (THOUSANDTHS OF DAILY MEAN)

II. *Marine Type.*

12 P.M—2 A.M.	88
2–4	93
4–6	93
6–8	90
8–10	84
10–Noon	76
Noon—2 P.M.	74
2–4	75
4–6	80
6–8	82
8–10	82
10–12 P.M.	83

Humidity and Cloudiness. Arrhenius gives the mean cloudiness for different latitudes as follows:

70° N.	60°	50°	40°	30°	20°	10°	Eq.	10°	20°	30°	40°	50°	60° S.
59	61	48	49	42	40	50	58	57	48	46	56	66	75

The higher latitudes of the temperate zones thus have a mean cloudiness which equals and even exceeds that of the equatorial belt. The amounts over the oceans and coasts are greater than inland. The belts of minimum cloudiness are at about lat. 30° N. and S. Over the continental interiors, the cloudiest season is summer, but the amount is never very large. Otherwise, winter is generally the cloudiest season, with a fairly high mean annual amount.

The absolute humidity, as a whole, decreases as the

temperature falls. The relative humidity averages ninety per cent., more or less, over the oceans, and is high under the clouds and rain of cyclonic storms, but depends, on land, upon the wind direction; winds from an ocean or from a lower latitude being damper, and those from a continent or from a colder latitude being drier.

Seasons: Their Effects on Man. Seasons in the temperate zones are classified according to temperature—not, as in the tropics, by rainfall. The four seasons are important characteristics of these zones, especially of the middle latitudes of the north temperate zone. Here spring and autumn intervene as transition seasons between the colder winter with snow, and warmer summer with more or less rain. Towards the equatorial margins of the zones, the difference in temperature between summer and winter becomes smaller, and the transition seasons weaken and even disappear. At the polar margins, the change from winter to summer, and *vice versa,* is so sudden that there also the transition seasons disappear. These seasonal changes are of the greatest importance in the life of man.

Weather. An extreme changeableness of the weather, depending on the succession of cyclones and anticyclones, is another characteristic. For most of the year and most of the zone, settled weather is unknown. The changes are most rapid in the northern portion of the north temperate zone, especially on the continents, where the cyclones travel fastest. The

nature of these changes depends on the degree of development, the velocity of progression, the track, and other conditions of the disturbance which produces them. The changes may be sudden and marked, or faint and slow; the wind may back or veer; the precipitation may be heavy or light; the wind velocity may be light, or of hurricane force; anticyclones may be clear, or may have clouds, and not infrequently, precipitation. There is an almost endless variety of such examples. The detailed study of these varying phases of cyclonic and anticyclonic weather controls belongs to meteorology. It suffices here to say that the particular weather types resulting from this control give the climates their distinctive character, and that the study of climate through these types is the only method of appreciating the actual conditions. Annual and monthly averages of the different climatic elements alone are misleading, and give but a lifeless picture. The cyclonic unit, although its period is irregular and of varying length, is an essential basis of computation and comparison.

The weather types vary with the season and with the geographical position. They result from a combination, more or less irregular, of periodic, diurnal elements, under the regular control of the sun, and of non-periodic cyclonic and anticyclonic elements. In summer, on land, when the cyclonic element is weakest and the solar control is the strongest, the dominant types are associated with the regular changes from day to night. Daytime cumulus

clouds; diurnal variation in wind velocity; afternoon thunderstorms, with considerable regularity, characterise the warmest months over the continents and present an analogy with tropical conditions. Cyclonic and anticyclonic spells of hotter or cooler, rainy or dry, weather, with varying winds differing in the temperatures and the moisture which they bring, serve to break the regularity of the diurnal types. On the oceans, the diurnal characteristics are much less marked.

In winter, the non-periodic, cyclonic control is strongest. Local conditions of heat and cold become subordinate to the general control by the cyclone, which imports weather from a distance. The irregular changes from clear to cloudy, from warmer to colder, from dry air to snow or rain, extend over large areas and show little diurnal control. Spring and autumn are transition seasons and have transition weather types. In spring, the growing diurnal quality is marked by the increasing importance of local controls; the appearance of convectional phenomena such as spring rains; the struggle between the cyclonic and the solar controls of temperature, now one and now the other being paramount, but the latter gaining and the former losing. Cold spells, with cyclonic winds and clouds, recall winter. Warm spells, with marked diurnal temperature range, presage summer. In autumn, the decreasing frequency and importance of diurnal phenomena, such as thunder-showers, high afternoon temperatures, and the

like; the active radiation and cooling during the longer nights, with resulting fogs; and the increasing control by the cyclone, point to winter's coming.

Weather types thus differ with the seasons. They differ also in continental and marine climates. They differ according to topography and cyclonic and anticyclonic tracks. The oceans in the south temperate zone have a constancy of non-periodic cyclonic weather changes through the year which resembles only faintly that over the oceans of the northern hemisphere. Winter types differ little from summer types. The diurnal control is never very strong. Stormy weather prevails throughout the year, although the weather changes are more frequent and stronger in the colder months.

Climatic Subdivisions. From whatever point of view the temperate zones be considered, it is clear that there are fundamental differences between the north and south temperate. The latter is sufficiently individual to be given a place by itself. The marginal sub-tropical belts must also be considered as a separate group by themselves. The north temperate zone as a whole includes large areas of land, stretching over many degrees of latitude, as well as of water. Hence it embraces so remarkable a diversity of climates that no single district can be taken as typical of the whole. Its climate has been called "a crazy quilt of patches." It is a zone of marked seasonal variations and of great extremes, annual, diurnal, cyclonic. The simplest and most rational scheme for a classification

of these climates is based on the fundamental differences which depend upon land and water, upon the prevailing winds, and upon altitude. Thus there are the ocean areas and the land areas. The latter are then subdivided into western (windward) and eastern (leeward) coasts, and interiors. Mountain climates remain as a separate group.

South Temperate Zone. If the climate of the north temperate zone is "a crazy quilt of patches," that of the south temperate is a piece of fairly uniform texture and appearance throughout. This is the effect of the large ocean surface. The whole meteorological régime is more uniform than in the northern zone. Although the solar climate of the southern hemisphere is more severe than that of the northern, the physical climate is very much less extreme. It has been pointed out that this zone may properly be called "temperate"; that its temperature changes are small; its prevailing winds are stronger and steadier than in the northern hemisphere; its seasons more uniform; its weather prevailingly stormier, more changeable, and more under cyclonic control. The uniformity of the climatic conditions over the far southern oceans is monotonously unattractive. The continental areas are small, and develop to a limited degree only the more marked seasonal and diurnal changes which are characteristic of lands in general. The summers are less stormy than the winters, but even the summer temperatures are not high. Such an area as that of New Zealand,

with its mild climate and fairly regular rains, is really at the margins of the zone, and has much more favourable conditions than do the islands farther south. These islands, in the heart of this zone, have dull, cheerless, and inhospitable climates, with snow sometimes in midsummer. The zone enjoys a good reputation for healthfulness, which fact has been ascribed chiefly to the strong and active air movement, the relatively drier air than in corresponding northern latitudes, and the cool summers. It must be remembered, also, that the lands are mostly in the sub-tropical belt, which possesses peculiar climate advantages, as will be seen. The northern oceans repeat, in a much modified form, many of the characteristics of the south temperate oceans. Except to leeward of the broad lands, the northern oceans have the conservative features typical of marine climates the world over.

Sub-tropical Belts: Mediterranean Climates. At the tropical margins of the temperate zones, in the latitudes of the tropical high pressure areas, are the so-called sub-tropical belts. Far enough from the equator to be free from continued high temperatures, and near enough to it to be spared the extreme cold of higher latitudes, these transition belts are among the most favoured of the world. Their rainfall régime is alternately that of the westerlies and of the trades. They are thus associated, now with the temperate, and now with the tropical zones. In winter, the equatorward migration of the great pressure and

wind systems brings these latitudes under the control of the westerlies, whose frequent irregular storms give a moderate winter precipitation. These winter rains recall the winter trade rains of the tropics, although their origin is different. They are not steady and continuous, but are separated by spells of fine, sunny weather. The amounts vary greatly.[1]

In summer, when the trades are extended polewards by the outflowing equatorward winds on the eastern side of the ocean highs, mild, dry, and nearly continuous fair weather prevails, with general northerly winds.

The sub-tropical belts of winter rains and dry summers are not very clearly defined. They do not extend continuously around the world. They are mainly limited to the western coasts of the continents, and to the islands off these coasts, in latitudes between about 28° and 40°. Their degree of development and their importance vary in different longitudes. The sub-tropical belt is exceptionally wide in the eastern hemisphere, and reaches far inland there, embracing the countries bordering on the Mediterranean in southern Europe and northern Africa, including the Azores and the famous Riviera, and then extending eastward across the Dalmatian coast and the southern part of the Balkan peninsula into Syria, Mesopotamia, Arabia north of the tropic, Persia, and the adjacent lands. In the great eastward extension

[1] In round numbers, Lisbon has 28.60 inches; Madrid, 16.50; Algiers, 28.15; Nice, 33.00; Rome, 29.90; Ragusa, 63.90.

of the winter rains in this area, the development of secondary lows over the Mediterranean Sea is an important factor. The fact that the Mediterranean countries are so generally included in this belt has led to the use of the name "Mediterranean climates." Owing to the great irregularity of topography and outline, the Mediterranean province embraces many varieties of climate, but the dominant characteristics are the mild temperatures, except on the higher elevations, and the sub-tropical rains.

On the west coasts of the two Americas, the sub-tropical belt of winter rains is clearly seen in California and in northern Chile, on the west of the coast mountain ranges. Between the region which has rain throughout the year from the stormy westerlies, and the districts which are permanently arid under the trades, there is an indefinite belt over which rains fall in winter. In southern Africa, which is controlled by the high pressure areas of the South Atlantic and South Indian oceans, the south-western coastal belt has winter rains, decreasing to the north, while the east coast and adjoining interior have summer rains, from the south-east trade. There is sub-tropical vegetation on the south-east coast, and a cool, dry climate on the south-west coast. Southern Australia is climatically similar to south Africa. In summer, the trades give rainfall on the eastern coast, which decreases inland. In winter, the westerlies give moderate rains, chiefly on the south-western coast. Northern Chile, California, south-western Australia,

and the Cape province of Africa are thus all in the sub-tropical belt.

FIG. 23. MONTHLY DISTRIBUTION OF RAINFALL: SUB-TROPICAL WINTER RAINS

M: Malta. W. A: Western Australia

The sub-tropical climates follow the tropical high pressure belts across the oceans, but they do not retain their distinctive character far inland from the west coasts of the continents (except in the Mediterranean case), nor on the east coasts. On the latter, summer monsoons and the occurrence of general summer rains interfere, as in eastern Asia and in Florida, and to some extent in South America east of the Andes.

Strictly winter rains, with a maximum in December or in June, according to the hemisphere, are typi-

cal of the coasts and islands of this belt. The more continental areas have a tendency to spring and autumn rains. The rainy and dry seasons are most marked at the equatorward margins of the belt, and thus recall the tropical characteristic of dry and wet, rather than cold and hot seasons. With increasing latitude, the rain is more evenly distributed through the year, the summer becoming more and more rainy until, in the continental interiors of the higher latitudes, the summer becomes the season of maximum rainfall. The monthly distribution of rainfall in two sub-tropical regions is shown in the accompanying data and curves (see Fig. 23).

ANNUAL MARCH OF RAINFALL: SUB-TROPICAL TYPE (in thousandths of the annual mean).

	Western Australia	Southern Italy Sicily Malta
Latitude	32.3° S.	About 38° N.
January	14	130
February	18	93
March	30	98
April	64	75
May	150	35
June	183	23
July	168	8
August	166	28
September	93	73
October	59	133
November	32	144
December	23	160

The following table (from Supan), giving the seasonal distribution of rainfall in southern Europe, in

percentages of the annual mean, shows very clearly the change in the rainfall season in going from north to south. In the northern Tyrol, the normal type of central Europe prevails. In Sicily, the summer is almost rainless: the sub-tropical type is fully developed.

SEASONAL DISTRIBUTION OF RAINFALL IN CENTRAL AND SOUTHERN EUROPE (in percentages of the annual mean).

	Winter	Spring	Summer	Autumn
Northern Tyrol	16	24	37	23
Southern Tyrol	14	26	28	32
Po Valley	20	26	24	30
Central Italy	25	24	17	34
Southern Italy	31	25	11	33
Sicily	39	22	3	36
Malta	48	14	2	36

In Alexandria the dry season lasts nearly eight months; in Palestine, from six to seven months; in Greece, about four months.

The sub-tropical rains are peculiarly well developed on the eastern coast of the Atlantic Ocean, and are clearly illustrated in the accompanying diagram, after Supan (see Fig. 24).

The different types of rainfall are as follows:

I. North of lat. 40° N. Rain throughout the year.
II. Lats. 40°–27° N. Dry in summer (sub-tropical rains).
III. Lats. 27°–19° N. Always deficient in rainfall.
IV. Lats. 19°–7° N. Dry in winter (tropical rains).
V. Lats. 7°–1° N. Always rainy (equatorial belt).

VI. Lats. 1° N.–17° S. Dry in winter (tropical rains).
VII. Lats. 17°–30° S. Always dry.
VIII. Beyond lat. 30° S. Dry in summer (sub-tropical rains).
(IX. Always rainy on the oceans. The African west coast does not extend into this zone.)

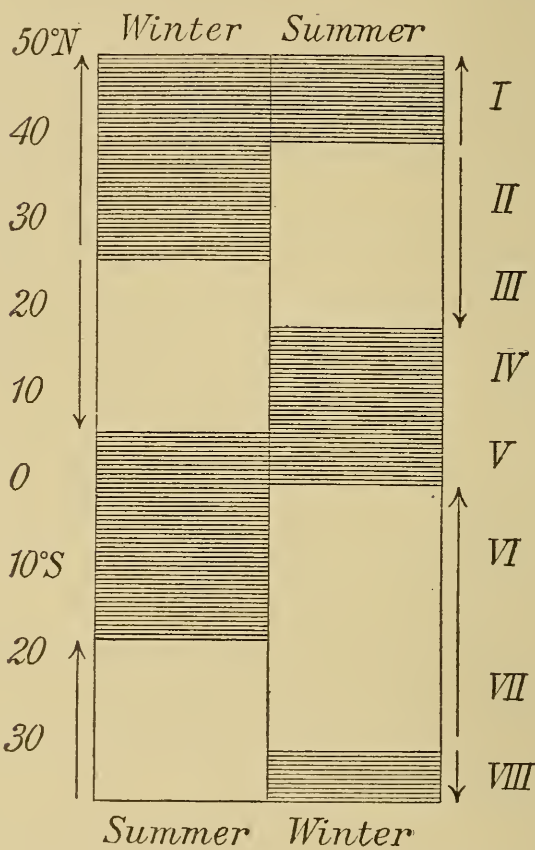

FIG. 24. RAINY AND RAINLESS ZONES ON EASTERN ATLANTIC COAST

The winter rains which migrate equatorward are separated by the Sahara from the equatorial rains which migrate poleward. An unusually extended migration of either of these rain belts may bring them

close together, leaving but a small part, if any, of the intervening desert actually rainless. The Arabian desert occupies a somewhat similar position. Large variations in the annual rainfall, and droughts, may be expected towards the equatorial margins of the sub-tropical belts. Irrigation is practised in many places.

TABLE OF MEAN MONTHLY TEMPERATURES FOR SELECTED SUB-TROPICAL STATIONS.[1]

	Continental		Insular	
	Bagdad	Cordoba	Bermuda	Auckland
Lat.	33°19′ N.	31°25′ S.	32°20′ N.	36°50′ N.
Long.	44°26′ E.	64°12′ W.	64°43′ W.	174°51′ E.
Altitude	39 ft.	1440 ft.	148 ft.	276 ft.
January	50.9°	73.4°	62.4°	67.1°
February	53.1	72.3	61.9	67.5
March	62.1	68.4	61.7	65.5
April	69.3	61.0	64.4	61.5
May	82.0	54.5	69.6	56.7
June	89.6	49.1	74.8	53.2
July	92.8	50.0	78.8	51.8
August	92.7	54.3	80.1	52.2
September	85.6	58.6	78.1	54.5
October	76.5	63.5	73.4	57.4
November	62.1	68.5	67.6	60.3
December	52.5	71.8	63.7	64.8
Mean	72.4	62.1	69.7	59.4
Range	41.9	24.3	18.4	15.7

The main features of the sub-tropical rains east of the Atlantic are repeated on the Pacific coasts of the

[1] Given to nearest tenth of a degree Fahr.

two Americas. In North America, the rainfall decreases from Alaska, Washington, and northern Oregon southwards to Lower California, and the length of the summer dry season increases. The mean annual rainfall (1871–1901) at Neah Bay, Wash., is 112.40 inches; at San Francisco, Cal., 22.83 inches, and at San Diego, Cal., 9.40 inches. At San Diego, six months (May-October) have each less than five per cent. of the annual precipitation, and four of these have one per cent. The southern extremity of Chile, from about latitude 38° S. southward, has heavy rainfall throughout the year from the westerlies, with a winter maximum. Northern Chile is persistently dry. In the intermediate area there are winter rains and dry summers. Neither Africa nor Australia extends far enough south to show the different members of this system well. New Zealand is almost wholly in the prevailing westerly belt. Northern India is unique in having summer monsoon rains, and also winter rains from weak cyclonic storms, which correspond to the sub-tropical winter rains.

From the position of the sub-tropical belts to leeward of the oceans, and at the equatorial margins of the temperate zones, it follows that their temperatures are not extreme. Further, the protection afforded by mountain ranges, as by the Alps in Europe and the Sierra Nevada in the United States, is an important factor in keeping out extremes of winter cold. The annual march, and ranges, of temperature de-

pend upon position with reference to continental or marine influences. This is seen in the accompanying data and curves for Bagdad, Cordoba, Bermuda, and Auckland (see Fig. 25).

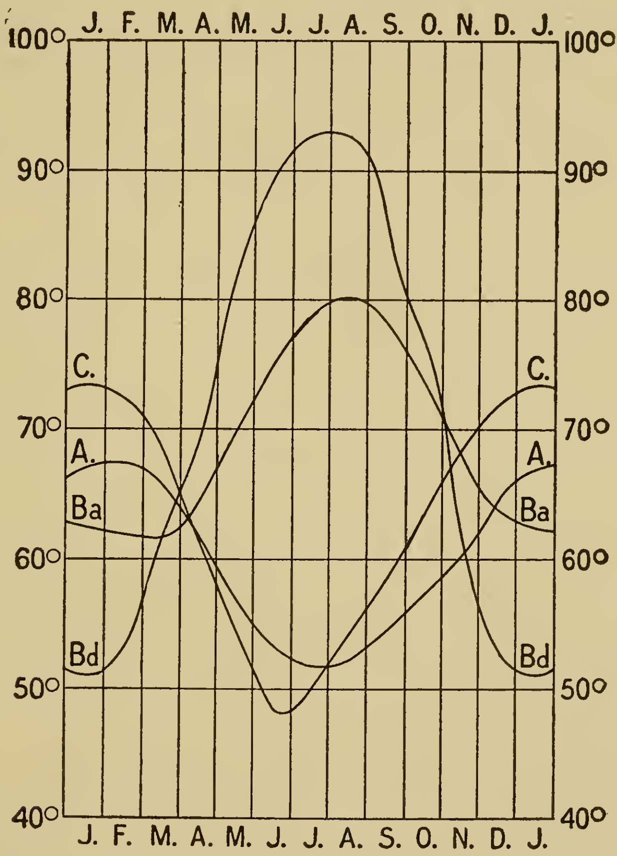

FIG. 25. ANNUAL MARCH OF TEMPERATURE FOR SELECTED SUB-TROPICAL STATIONS
Bd: Bagdad. Ba: Bermuda. A: Auckland. C: Cordoba

Autumn is, as a rule, a good deal warmer than spring, as in all the eastern Mediterranean basin, the Canaries, and Madeira. This basin is particularly

favoured in winter, not only in the protection against cold afforded by the mountains, but also in the high temperature of the sea itself. The southern Alpine valleys and the Riviera are well situated, having good protection and a southern exposure. The coldest month usually has a mean temperature well above 32°. Mean minimum temperatures of about, and somewhat below, freezing occur in the northern portion of the district,[1] and in the more continental localities minima a good deal lower have been observed. (At San Diego, Cal., the absolute minimum is 32°; at San Francisco, 29°.) Mean maximum temperatures of about 95° occur in northern Italy, and of still higher degrees in the southern portions. Somewhat similar conditions exist in the sub-tropical district of North America. Under the control of passing cyclonic storm areas, hot or cold winds, which often owe some of their special characteristics to the topography, bring into the sub-tropical belts, from higher or lower latitudes, unseasonably low or high temperatures. These winds have been given special names (mistral, sirocco, bora, chamsin, leste, leveche, pampero, southerly burster, etc.)

These belts enjoy abundant sunshine, being among the least cloudy districts in the world. The accompanying data and curve, giving an average for ten stations, show the small annual amount of cloud, the winter maximum and the marked summer minimum, in a typical sub-tropical climate. (Fig. 26).

[1] Nice, 30.4°; Rome, 25.7°; Palermo, 32°; Athens, 28.8°.

MONTHLY DISTRIBUTION OF CLOUDINESS IN A SUB-TROPICAL CLIMATE (EASTERN MEDITERRANEAN, LAT. 33.8° N.)

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
4.9	4.6	3.8	3.7	2.8	1.3	1.1	1.3	1.8	2.5	4.0	4.7	3.0

The winter rains do not bring continuously overcast skies; and it has been well said that the problem of securing a maximum rainfall with a maximum number of clear days has been solved on the southern Alpine slopes. A summer month with a mean

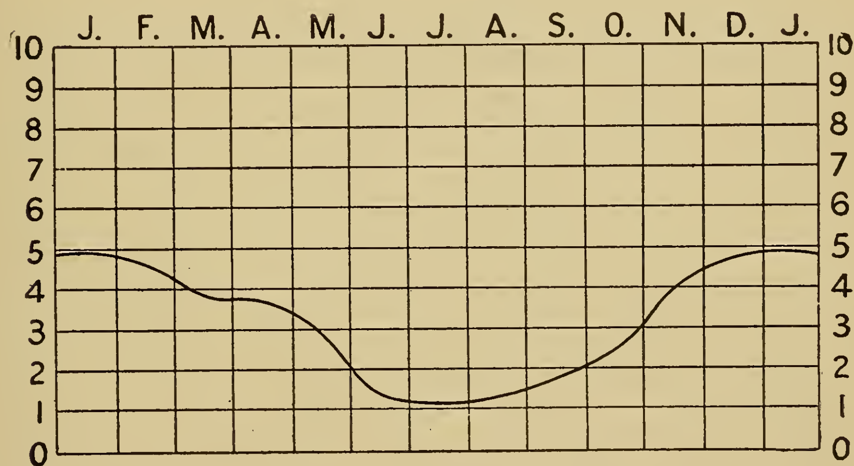

FIG. 26. ANNUAL MARCH OF CLOUDINESS IN A SUB-TROPICAL CLIMATE (Eastern Mediterranean)

cloudiness of 0.1 is not exceptional in the drier parts of the sub-tropics. The winter cloudiness in northern Italy is 5.0 to 6.0; in summer, 3.0 to 4.0. Cairo has an annual mean of 1.9, and in June it has 0.8. Biskra, on the northern margin of the Sahara, has 264 clear days. In the central valley of Cali-

fornia, the number of clear days is similarly very large.

With prevailingly fair skies, even temperatures, and moderate rainfall, the sub-tropical belts possess many climatic advantages which fit them for health resorts. The long list of well-known resorts on the Mediterranean coast, and the shorter list for California, bear witness to this fact.

North Temperate Zone: West Coasts. Marine climatic types are carried by the prevailing westerlies on to the western coasts of the continents, giving them mild winters and cool summers, abundant rainfall and a high degree of cloudiness and relative humidity. North-western Europe is particularly favoured because of the remarkably high temperatures of the North Atlantic Ocean, and because of the influence of the winds controlled by the low pressure area off Iceland. In January, north-western Europe has temperatures from 20° to 40° in excess of the normal for the latitude. The north-western coast of North America has temperatures more than 10° too warm for the latitude. January means of 40° to 50° in the British Isles and on the northern French coast occur in the same latitudes as those of 0° and 10° in the far interior of Asia. In July, means of 60° to 70° in the former contrast with 70° and 80° in the latter districts. The conditions are somewhat similar in North America. Along the western coasts of North America and of Europe the mean annual ranges are under 25°,—actually no greater than some

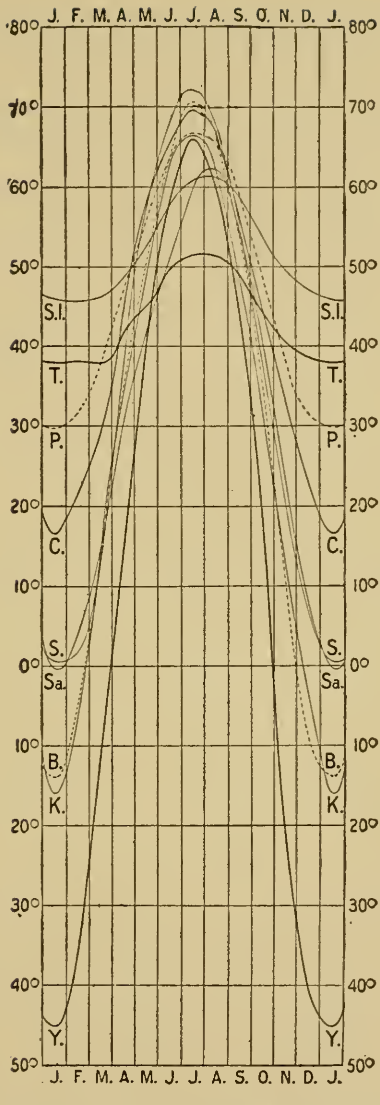

FIG. 27. ANNUAL MARCH OF TEMPERATURE FOR SELECTED STATIONS IN THE TEMPERATE ZONES

S. I: Scilly Isles. P: Prague. C: Charcow. S: Semipalatinsk. K; Kiakhta. B: Blagoweschtschensk. Sa: Sakhalin. T: Thorshavn. Y: Yakutsk

of those within the tropics. Irregular cyclonic temperature changes are, however, marked in the temperate zone, while absent in the tropics. The data and curves for the Scilly Isles and for Thorshavn, Faroe Islands, illustrate the insular type of temperature on the west coasts (see Fig. 27). In the Faroes the mean maximum is 65.1°, and the mean minimum 16°. It will be noted that the poleward decrease in the mean annual and the mean winter temperatures is very slow between latitudes 50° and 62° N. on the west coast of Europe.

TABLE OF MEAN MONTHLY TEMPERATURES FOR SELECTED STATIONS IN THE TEMPERATE ZONES.

	Along lat. 50° N.							At lat. 62°N.	
	West Coast	Continental					East Coast	Insular	Continental
	Scilly Isles	Prague	Charcow	Semipalatinsk	Kiakhta	Blagoweschtschensk	Sakhalin	Thorshavn, Faroe Isles	Yakutsk, E. Siberia
Lat.	49°55′	50°5′	50°2′	50°24′	50°21′	50°15′	50°50′	62°2′	62°1′
Long.	6°20′ W.	14°26′ E.	36°11′	80°13′	106°31′	127°38′	142°7′ E.	6°44′ W.	129°43′E
Alt. (ft.)	98.4	662.7	413.4	593.8	2526	360.9	180.4	29.5	328.1
Jan.	45.7°	29.8°	16.5°	0.5°	−15.9°	−13.9°	−0.4°	37.8°	−45.2°
Feb.	45.7	32.0	22.1	1.8	−5.4	−3.3	5.0	38.1	−35.0
March	46.0	37.8	29.3	14.4	16.9	14.4	15.8	37.8	−10.7
April	48.7	47.3	44.8	38.3	34.3	34.7	31.1	41.9	15.1
May	52.5	55.9	58.8	57.2	48.7	49.6	41.4	45.0	40.3
June	57.9	63.3	65.1	68.0	63.1	63.7	50.7	49.5	58.5
July	60.8	66.7	69.6	72.0	66.4	70.5	60.3	51.4	65.8
Aug.	61.2	65.3	66.4	67.3	61.7	65.8	62.2	51.3	59.7
Sept.	58.6	58.8	56.1	54.9	48.0	53.2	53.6	48.7	42.3
Oct.	54.0	48.7	45.5	38.1	32.0	34.2	39.6	43.9	15.8
Nov.	49.6	37.6	33.8	20.1	11.8	9.7	22.5	40.6	−21.3
Dec.	47.3	31.3	23.2	6.1	−2.7	−9.2	7.3	38.1	−41.1
Year	52.3	47.9	44.3	36.5	29.9	30.8	32.4	43.7	12.0
Range	15.5	36.9	53.1	71.5	82.3	84.4	62.6	13.6	111.0

MONTHLY DISTRIBUTION OF RAINFALL (IN THOUSANDTHS OF THE ANNUAL MEAN). TEMPERATE ZONE.

	Continental Summer Rains		Coast Rains	
	Moderate	Very heavy	Uniform Distribution	Fall and Winter Rains
	Central Europe North of Alps	Northern Asia	Atlantic Coast, North America	North-west Europe
Lat.	About 50° N.	About 55° N.	About 40° N.	About 60° N.
January	57	20	84	100
February	56	17	77	80
March	68	18	85	72
April	71	35	70	56
May	92	75	80	58
June	115	235	81	64
July	121	215	96	70
August	117	122	87	80
September	82	133	84	102
October	75	58	91	110
November	74	40	86	102
December	72	32	79	106

The monthly distribution of rainfall, with the marked maximum in the fall and winter which is characteristic of the marine régime, is illustrated in the last column of the table above, for north-western Europe, and in the corresponding curve (see Fig. 28).

On the northern Pacific coast of North America, the distribution is similar. Thus at Olympia, Washington, there is a distinct cold season maximum, as appears in the following data:

MONTHLY DISTRIBUTION OF RAINFALL AT OLYMPIA, WASHINGTON (IN THOUSANDTHS OF THE ANNUAL MEAN).

January	159
February	135
March	95
April	65
May	44
June	31
July	13
August	13
September	53
October	86
November	124
December	182

In the southern hemisphere, the western coasts of southern South America, Tasmania, and New Zealand show the same type.

The cloudiness and relative humidity average high on western coasts, with the maximum in the colder season. The difference in general rainfall conditions between the west coast, typified by the exaggerated case of Valentia, in south-western Ireland, and the Mediterranean, is seen in the number of rainy days in each district. Valentia has nearly 250. In the Mediterranean, they may be set down as about 100, in round numbers.

The west coasts, therefore, including the important climatic province of western Europe, and the coast provinces of north-western North America, New Zealand, and southern Chile, have, as a whole, mild winters, equable temperatures, small ranges, and

abundant rainfall, fairly well distributed through the year. The summers are relatively cool, especially on the Chilean coast.

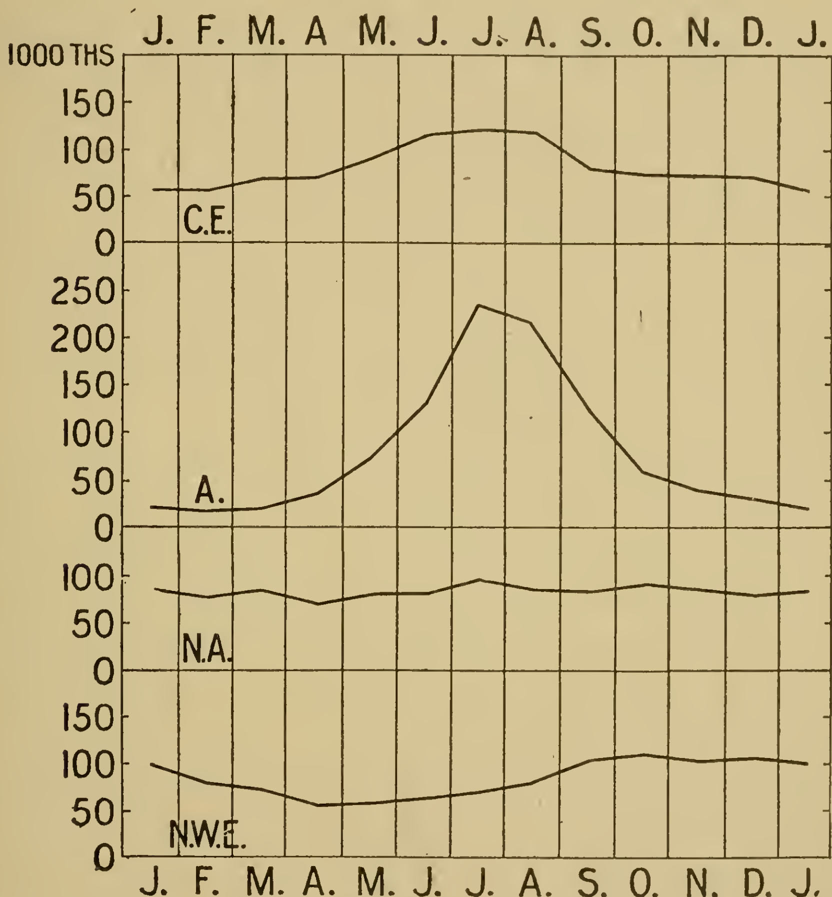

FIG. 28. ANNUAL MARCH OF RAINFALL: TEMPERATE ZONES
C. E: Central Europe. A: Northern Asia. N. A: Atlantic Coast of North America, N. W.E: Northwest Europe

Continental Interiors. The equable climate of the western coasts changes, gradually or suddenly, into the more extreme climates of the interiors. In Europe, where no high mountain ranges intervene,

the transition is gradual, and broad stretches of country have the benefits of the tempering influence of the Atlantic. In North America, the change is abrupt, and comes on crossing the lofty western mountain barrier. The data in the table on page 136, and the corresponding curves in Fig. 27, illustrate well the gradually increasing severity of the climate with increasing distance inland in Eurasia. Central Europe is seen to lie between the modified marine climate of the west coast and the continental conditions of Russia and Siberia. Its mean temperatures do not differ very much from those on the coast, but the seasons are more sharply contrasted.

The continental interiors of the north temperate zone have the greatest extremes in the world. Towards the Arctic circle, the winters are extremely severe, and January mean temperatures of —10° and —20° occur over considerable areas. At the cold pole of northern Siberia a January mean of —60° is found. Mean minimum temperatures of —40° occur in the area from eastern Russia, over Siberia and down to about latitude 50° N. At Verkhoyansk, an important town just beyond the Arctic circle, the absolute minimum is below —90°. Over no small part of Siberia minimum temperatures below —70° may be looked for every winter. Thorshavn and Yakutsk (see table on page 136) are excellent examples of the temperature differences along the same latitude line. The winter in this interior region is dominated by a marked high pressure. The weather is

prevailingly clear and calm. The ground below a slight depth is frozen the year around, over wide areas. The moderate snowfall is sufficient, with the continued cold, to make sleighing possible for immense stretches all over the country. The frozen rivers can be crossed without bridges. This unifying influence, of easy winter communication, has been most important in Russian history, as Leroy-Beaulieu has pointed out. The extremely low temperatures are not disagreeable except when the steppes are swept by icy storm winds (buran, purga), carrying loose snow, and often resulting in loss of life.

In the North American interior, the winter cold is somewhat less severe. The lowest January mean temperatures are —30°, in the extreme northern portion of the continent. Mean annual minima of —40° occur down into the northern interior portion of the United States. The lowest is about —60°, near Great Bear Lake, with an absolute minimum of about —72°. North American winter weather in middle latitudes is often interrupted by cyclones, which, under the steep poleward temperature gradient then prevailing, cause frequent, marked, and sudden changes in wind direction and temperature over the central and eastern United States. Cold waves and warm waves are common, and blizzards resemble the buran or purga of Russia and Siberia. With cold northerly winds, temperatures below freezing are carried far south towards the tropic. The January mean tem-

peratures in the southern portions of the continental interiors average about 50° or 60°.

In summer, the northern continental interiors are warm, with July means of 60° and thereabout. These temperatures are not much higher than those on the west coasts, but as the northern interior winters are much colder than those on the coasts, the interior ranges are very large. The mean annual extreme ranges exceed 150° in northern North America and 170° in Siberia. Mean maximum temperatures of 85° occur beyond the Arctic circle in north-eastern Siberia, and beyond latitude 60° in North America. In spite of the extreme winter cold, agriculture extends remarkably far north in these regions, because of the warm, though short, summers, with favourable rainfall distribution. The July isotherm of 50° is about the northern limit of tree growth. Beyond a zone of stunted tree growth, comes the tundra. The summer heat is sufficient to thaw the upper surface of the frozen ground, and vegetation prospers for its short season. At this time, great stretches of flat surface become swamps. The southern interiors have torrid heat in summer, temperatures of over 90° being recorded in the south-western United States and in southern Asia. In these districts the diurnal ranges of temperature are very large, often exceeding 40°, and the mean maxima exceed 110°.

In South America, the interior of Argentina has moderate mean annual ranges (20°–30°); the mean

maxima reach 95°–100° and even higher, and the mean minima fall below 23°. The west coast has smaller ranges (less than 20°); lower mean maxima (77°–86°), and higher mean minima (32°–23°).

The winter maximum rainfall of the west coasts becomes a summer maximum in the interiors. The change is gradual in Europe, as is the change in temperature, but more sudden in North America. The curves for central Europe and for northern Asia (see Fig. 28) illustrate these continental summer rains. The summer maximum becomes more marked with the increasing continental character of the climate. Thus, while June to August in central Europe supply about thirty-five per cent. of the annual precipitation, in northern Asia, excluding the coast, they give nearly sixty per cent. The rains of Asia are actually comparable, in relative intensity, at their maximum, with the rains of the tropics. In Bengal, *e. g.*, June to August give only fifty-seven per cent. of the annual rainfall. The winter dry season of Asia is, however, very different from a tropical dry season, because of the difference in conditions of vegetation and of snow cover. In North America, Nebraska, a state which is typical of a considerable district of summer rains, receives about sixty per cent. of the annual rainfall in the months of April, May, June, and July.

The change in rainfall season with increasing distance from the Atlantic Ocean in Eurasia is well brought out by Supan in the following table:

TABLE SHOWING SEASONAL DISTRIBUTION OF RAINFALL IN EURASIA (IN PERCENTAGES OF THE ANNUAL MEAN).

	Winter	Spring	Summer	Autumn
Ireland	28	21	24	27
Western England	28	19	24	29
Eastern England	23	19	28	30
North-western Germany	23	22	31	24
Central Germany	20	23	34	23
Eastern Germany	19	22	37	22
Western Russia	16	21	39	24
Central Russia	16	22	37	25
Western Siberia	13	13	42	32
Eastern Siberia	9	12	58	21

There is also a well-marked decrease in the amount of rainfall inland. In western Europe, the rainfall averages 20–30 inches, with much larger amounts (reaching 80–100 inches and even more) on the bold west coasts, as in the British Isles and Scandinavia, where the moist Atlantic winds are deflected upwards, and also locally on mountain ranges, as on the Alps. There are small rainfalls (below 20 inches) in eastern Scandinavia and on the Iberian peninsula. Eastern Europe has generally less than 20 inches; western Siberia about 15 inches, and eastern Siberia about 10 inches. In the southern part of the great overgrown continent of Asia, an extended region of steppes and deserts, too far from the sea to receive sufficient precipitation, shut in by mountains, and controlled in summer by drying northerly winds, receives less than 10 inches a year, and in places less than 5 inches. In this interior district of Asia, population is inevitably small, and suffers under a condition of hopeless aridity.

The North American interior has more favourable rainfall conditions than Asia, because the former continent is narrower. The heavy rainfalls on the western slopes of the Pacific coast mountains correspond, in a general way, to those on the west coast of Europe, although they are heavier (over 100 inches at a maximum). The close proximity of the mountains to the Pacific, however, involves a much more rapid decrease of rainfall inland than is the case in Europe, as may be seen by comparing the isohyetal lines in the two cases. The rain-shadow influence of the Pacific coast Cordilleras extends about half-way across the continent. A considerable interior region is left with deficient rainfall (less than 10 inches) in the south-west. The eastern portion of the continent is freely open to the Atlantic and the Gulf of Mexico, so that moist cyclonic winds have free access, and rainfalls of over 20 inches are found everywhere east of the 100th meridian. These conditions are much more favourable than those in eastern Asia. The greater part of the interior of North America has the usual warm-season rains. In the interior basin, between the Rocky and Sierra Nevada mountains, the higher plateaus and mountains receive much more rain than the desert lowlands. Forests grow on the higher elevations, while irrigation is necessary for agriculture on the lowlands. The rainfall here comes chiefly from thunder-storms.

In southern South America, the narrow Pacific slope has heavy rainfall (over 80 inches). East of

the Andes the plains are dry (mostly less than 10 inches). The southern part of the continent is very narrow, and is open to the east. It is also more open to the west than is the country farther north, owing to the decreasing height of the mountains southward. Hence the rainfall increases somewhat to the south, coming in connection with passing cyclones. Tasmania and New Zealand have most rain on their western slopes.

In a typical continental climate, the winter, except for radiation fogs, is very clear, and the summer is the cloudiest season, as is well shown in the following data and curve for eastern Asia. In a more moderate continental climate, such as that of central Europe, and much of the United States, the winter is the cloudiest season (see Fig. 29).

MONTHLY DISTRIBUTION OF CLOUDINESS IN CONTINENTAL CLIMATES.

I. Eastern Asia. 10 stations. Lat. 56.5° N. Long. 115° E.

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
3.1	3.4	3.9	4.7	5.7	5.6	6.2	6.0	5.5	5.4	4.8	4.2	4.9

II. Central Europe. Hungarian Plain. Lat. 47° N.

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
6.5	5.9	5.7	5.6	5.4	5.3	4.4	4.2	4.6	5.8	6.6	6.9	5.6

In the first case, the mean cloudiness is small; in the second, there is a good deal of cloud all the year around.

The vast continental interiors, whose climatic features have here been outlined, can obviously be

subdivided into smaller climatic provinces almost indefinitely, as pointed out in Chapter III.

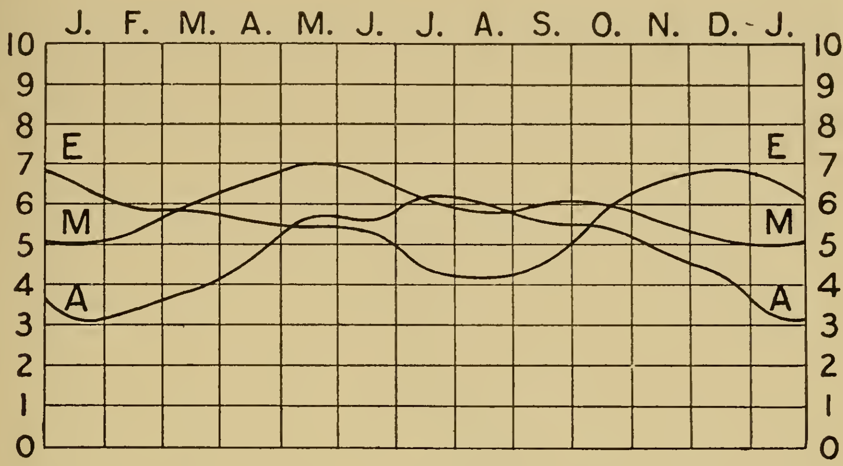

FIG. 29. ANNUAL MARCH OF CLOUDINESS IN CONTINENTAL AND MOUNTAIN CLIMATES: TEMPERATE ZONES.

E : Central Europe. A : Eastern Asia. M : Mountain

East Coasts. The prevailing winds carry the marine climate of the oceans on to the western coasts of the temperate zone lands. They also carry the continental climates of the interiors off over the eastern coasts of these same lands, and even for some distance on to the adjacent oceans. The east coasts, therefore, have continental climates, with modifications resulting from the presence of the oceans to leeward, and are necessarily separated from the west coasts, with which they have little in common. On the west coasts of the north temperate lands the isotherms are far apart. On the east coasts, they are crowded together. The east coasts share with the interiors large annual

and cyclonic ranges of temperature. At latitude 55° N., for example, the east coast of Asia has a mean annual range which is four times as large as that of the west coast. A glance at the isothermal maps of the world will show at once how favoured, because of its position to leeward of the warm North Atlantic waters, is western Europe as compared with eastern North America. A similar contrast, less marked, is seen in eastern Asia and western North America. In eastern Asia, there is some protection, by the coast mountains, against the extreme cold of the interior, but in North America there is no such barrier, and severe cold winds sweep across the Atlantic coast states, even far to the south. Owing to the prevailing offshore winds, the oceans to leeward have relatively little effect. In the north-east, the cold water is effective in giving cooler summers than farther south.

As already noted, the rainfall increases from the interiors towards the east coasts. In North America, the distribution through the year is very uniform, with some tendency to a summer maximum, as in the interior (see Fig. 28).

In eastern Asia the winters are relatively dry and clear, under the influence of the cold offshore monsoon, and the summers are warm and rainy, with the northward extension of the south-east monsoon, which reaches as far as lat. 60° N. The summer maximum of rainfall on this coast is clearly shown in the following data (Trabert):

MONTHLY DISTRIBUTION OF RAINFALL. EAST COAST OF ASIA.

(IN PERCENTAGES OF ANNUAL MEAN).

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
2	2	3	6	8	10	12	21	16	11	6	3	19.3 ins.

Rainfalls of 40 inches are found on the east coasts of Korea, Kamchatka, and Japan, while in North America, which is more open, they reach farther inland. Japan, although occupying an insular position, has a modified continental, rather than a marine climate. The winter monsoon, after crossing the water, gives abundant rain on the western coast, while the winter is relatively dry on the lee of the mountains, on the east. Japan has smaller temperature ranges than the mainland.

Mountain Climates. The mountain climates of the temperate zone have the usual characteristics which are associated with altitude everywhere. If the altitude is sufficiently great, the decreased temperature gives mountains a polar climate, with the difference that the summers are relatively cool, while the winters are mild, owing to inversions of temperature in anticyclonic weather. Hence the annual ranges are smaller than over lowlands. At such times of inversion, the mountain tops often appear as local areas of higher temperatures in a general region of colder air over the valleys and lowlands. The increased intensity of insolation aloft is an important factor in giving certain mountain resorts their deserved popularity in winter (*e. g.*, Davos and

Meran). Of Meran it has been well said that from December to March the nights are winter, but the days are mild spring. Mountains provoke rainfall, even in arid continental interiors, and thus we have well-forested plateaus and mountain slopes rising above desert lowlands. The diurnal ascending air currents of summer usually give mountains their maximum cloudiness and highest relative humidity in the warmer months, while winter is the drier and clearer season. This is shown in the data below (see Fig. 29).

MONTHLY DISTRIBUTION OF CLOUDINESS. MOUNTAIN CLIMATE.

(CENTRAL EUROPE. ALPINE SUMMITS. 8500 FT. LAT. 47° N. SEVEN STATIONS.)

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
5.0	5.3	6.0	6.5	7.0	6.7	6.1	5.8	6.0	6.0	5.5	5.1	5.9

The clouds of winter are low; those of summer are higher. Hence the annual march of cloudiness on mountains is usually the opposite of that on lowlands.

CHAPTER VI

THE CHARACTERISTICS OF THE ZONES: III.—THE POLAR ZONES

General: Relation to Man, Animals, and Plants—Temperature—Pressure and Winds—Rain and Snow—Humidity, Cloudiness, and Fog—Cyclones and Weather—Twilight and Optical Phenomena—Physiological Effects.

General: Relation to Man, Animals, and Plants. The temperate zones merge into the polar zones at the Arctic and Antarctic circles or, if temperature is used as the basis of classification, at the isotherms of 50° for the warmest month, as suggested by Supan. The frequent use of maps on the Mercator projection tends to give us an exaggerated idea of the size of the polar zones. When limited by the polar circles, these zones occupy but 0.08 of the surface of each hemisphere, the whole area being 1.00. Astronomically they are distinguished by the fact that at all places within them the sun is above the horizon at least one full twenty-four hours each year, and below it the same length of time. This longer or shorter absence of the sun gives the climate a peculiar character, not found elsewhere. At the poles, the day

and the year are alike. These zones obviously have the most oblique insolation.

For but a very small part of the polar zones have we any knowledge, by observation, of the *climate*. The fragmentary records of the earlier expeditions gave scattering information about the weather. The longer and more complete records of recent expeditions give much more accurate and satisfactory results. It is now becoming possible to see more clearly what the climatic conditions really are. But as yet no scientific presentation of polar climatology is possible. We are still dealing with the meteorology of the polar zones, rather than with their climates. More is known of the Arctic than of the Antarctic. From the latter there are already several excellent contributions, but up to this time no record both as long and as complete as that of the Nansen Expedition has been obtained. The admirable report, by Dr. Mohn, on the results of this expedition, embracing three years' observations, discussed with great care, and well illustrated by curves and charts, is a monumental piece of work. Under the able directorship of Mr. Walter G. Davis, however, the Argentine Meteorological Service is steadily accumulating observations at its far southern stations, on the South Orkney and South Shetland Islands, and although these stations are not within the Antarctic zone, they will furnish valuable information concerning the great ocean area surrounding this zone.

Beyond the isotherm of 50° for the warmest month,

forest trees and cereals do not grow. In the northern hemisphere this line is well north of the Arctic circle in the continental climate of Asia, and north of it in north-western North America. It is north of it also in northern Scandinavia, but falls well south in eastern British America, Labrador, and Greenland, and also in the North Pacific Ocean. In the southern hemisphere this isotherm crosses the southern extremity of South America, and runs nearly east and west around the globe.

In the Arctic climate, vegetation must make rapid growth in the short, cool summer. In the highest latitudes the summer temperatures are not high enough to melt snow on a level. Exposure is therefore of the greatest importance. Arctic plants grow and blossom with great rapidity and luxuriance where the exposure is favourable, and where the water from the melting snow can run off. The soil then dries quickly, and can be effectively warmed. On the other hand, when the water stands, it may freeze again and again, and the soil underneath has no opportunity to warm. Of Novaya Zemlya Baer has reported that the level surfaces are polar deserts, while the slopes at the foot of the mountains, unless covered with boulders, are like gardens in summer. Protection against cold winds is another important factor in the growth of this vegetation. Over great stretches of the northern plains the surface only is thawed out in the warmer months, and swamps, mosses, and lichens are found above eternally frozen ground.

Trees often grow in favourable conditions along streams when the intervening plains are typical tundras. Direct insolation is very effective in high latitudes. Where the exposure is favourable, snow melts in the sun even when the temperature of the air in the shade is far below freezing. It has been reported that at Assistance Bay (lat. 74½° N.), in March, when the air temperature was about $-25°$, snow near stones and other dark objects melted in the sun. Even the mean daily temperature of the snow surface may be higher than the air temperature. The injurious effect of polar climate upon vegetation, especially upon trees, has been attributed by Kihlmann to an insufficient water-supply furnished by the roots deep in the cold ground. From the upper parts of the tree, exposed to sunshine and wind, evaporation proceeds rapidly, and the tree dries up. Protective devices against excessive evaporation, not unlike those of desert plants, are found.

Arctic and Antarctic zones differ a good deal in the distribution and arrangement of land and water around and in them. The southern zone is surrounded by a wide belt of open sea; the northern, by land areas. The northern is therefore much affected by the conditions of adjacent continental masses. Nevertheless, the general characteristics are apparently much the same over both, so far as is now known, the Antarctic differing from the Arctic chiefly in having colder summers, and in the regularity of its pressure and winds. The cold Antarctic sum-

mers are the chief cause of the poverty of the Antarctic flora. Both zones have the lowest mean annual temperatures in their respective hemispheres, and hence may properly be called the *cold zones*.

FIG. 30. JANUARY NORTH POLAR ISOTHERMS

Temperature. At the solstices, the two poles receive the largest amounts of insolation which any part of the earth's surface ever receives. It would seem, therefore, that the polar temperatures should then be the highest in the world, but as a matter of fact they

are nearly or quite the lowest. Temperatures do not follow insolation in this case because much of the latter never reaches the earth's surface; because most

FIG. 31. JULY NORTH POLAR ISOTHERMS

of the energy which does reach the surface is expended in melting the snow and ice of the polar areas; and also because the water areas are large, and the duration of insolation is short. Hence the mean annual temperatures at both poles are nearly, or quite, the lowest in the world.

A set of monthly isothermal charts of the north polar area, based on all available observations, was prepared by Mohn and published in the volume on *Meteorology* of the Nansen Expedition. These charts give the most authentic information now at hand regarding Arctic temperatures. In the winter months there are three cold poles, in Siberia, in Greenland, and at the pole itself. In January, the mean temperatures at these three cold poles are —49°, —40°, and —40° respectively.

The Siberian cold pole becomes a maximum of temperature during the summer, but the Greenland and polar minima remain throughout the year. In April the lowest isotherm, — 22°, is in Greenland, and the north pole is then within the area enclosed by — 18.4°. In July the temperature distribution shows considerable uniformity; the gradients are relatively weak.

A large area in the interior of Greenland, and one of about equal extent around the pole, are within the isotherm of 32°. Hence the statement frequently made, that no places in the northern hemisphere have mean temperatures below freezing in July, is not correct. In October the interior of Greenland is enclosed by — 13°, and at the pole we find — 11.2°. For the year a large area around the pole is enclosed by the isotherm of — 4°, with an isotherm of the same value in the interior of Greenland, but a local area of — 7.6° is noted in Greenland, and one of — 11.2° is centred at lat. 85° N. and long. 170° E. It will be seen that the temperatures are relatively lower to-

wards the eastern sides of the great continents. The ordinary mean annual isothermal chart shows, within the Arctic circle, temperatures of 40° off the Norwegian coast and — 5° beyond lat. 75° N., north of

Fig. 32. Mean Annual North Polar Isotherms

Asia and North America. The January chart shows 30° off the Norwegian coast, and — 60° at Verkhoyansk, in Siberia. The July chart shows 60° over the continents, to 40° in extreme north-eastern Asia.

The north polar chart of annual range of temperature shows a maximum range of about 120° in Siberia; of 80° in North America; of 75.6° at the north pole, and of 72° in Greenland. The north pole obviously has a continental climate. The minimum ranges are on the Atlantic and Pacific oceans. The mean annual isanomalies show that the line of zero anomaly passes through the pole (as it must do). The interior of Greenland has a negative anomaly in all months. The Norwegian sea area is 45° too warm in January and February. Siberia has +10.8° in summer, and — 45° in January. Between Bering Strait and the pole there is a negative anomaly in all months. The influence of the Gulf Stream drift is clearly seen on this chart, as it is also on that of mean annual ranges.

The mean temperatures of the higher northern latitudes in January, July, and for the year have been determined by Mohn with the following result:

MEAN TEMPERATURES OF THE HIGHER NORTHERN LATITUDES.

	60°	65°	70°	75°	80°	85°
Jan.	+3.0°	−9.4°	−15.3°	−20.2°	−26.0°	−36.6°
July	57.4	54.3	45.1	38.1	35.6	32.5
Year	30.0	21.6	12.7	5.5	−0.6	−6.2

For the north pole itself, Mohn gives the following results, obtained by graphic methods:

MEAN TEMPERATURES OF THE NORTH POLE.

Jan.	Feb.	Mar.	Apr.	May	June	July
−41.8°	−41.8°	−31.0°	−18.4°	8.6°	28.4°	30.2°

Aug.	Sept.	Oct.	Nov.	Dec.	Year
26.6°	8.6°	−11.2°	−27.4°	−36.4°	−8.9°

It appears that the region about the north pole is the coldest place in the northern hemisphere for the mean of the year, and that the interior ice desert of Greenland, together with the inner polar area, are together the coldest parts of the northern hemisphere in July. In January, however, Verkhoyansk, in north-eastern Siberia, just within the Arctic circle, has a mean temperature of about — 60°, while the inner polar area and the northern interior of Greenland have only — 40°. Future exploration in the immediate vicinity of the north pole may show a lower January mean temperature there than at present appears. Such exploration will, moreover, certainly necessitate readjustment of the isothermal lines as now drawn for this polar area. It may be noted that the isotherm of 32° in January crosses the Arctic circle in the north-eastern Atlantic. Elsewhere it is south of this line. By December all land within the Arctic circle is below the freezing point. Thus far no minima as low as those of north-eastern Siberia have been recorded in the Arctic, and the Arctic maxima are much lower than those of Siberia. During the last Peary expedition, the winter of 1905–06 was distinguished by "comparatively high" temperatures.

For the Antarctic our knowledge is still very fragmentary, and relates chiefly to the summer months, but the numerous well-equipped expeditions of the last ten years have brought back very valuable results, extending in a few cases over all parts of the

year. On the February south polar isothermal chart published in 1898 (after Buchan), the isotherm of 30° was shown essentially coincident with the Antarctic circle, while a part of the isotherm of 25° was drawn inside of the circle. Using the newest data available, Hann has determined the mean temperatures of the higher southern latitudes as follows:[1]

MEAN TEMPERATURES OF HIGH SOUTHERN LATITUDES.

S. Lat.	50°	60°	70°	80°
Mean Annual	41.9°	28.4°	11.3°	−3.6°
January	46.9	37.8	30.6	20.3
July	37.2	18.3	−8.0	−24.7

These temperatures can be compared with those given on page 159, for northern latitudes. From lat. 70° S. polewards, Hann finds that the southern hemisphere is colder than the northern. Antarctic summers are decidedly cold. The mean temperature of the warmest month over the whole Antarctic zone is below the freezing point,[2] while within the Arctic circle mean temperatures above 32° are generally found, except in the interior of Greenland and around the pole. The low temperatures of the south polar summer, which are probably due to the great continental mass of ice around the south pole, are responsible for much of the difficulty and disa-

[1] *Nature*, Jan. 5, 1905, p. 221.

[2] At Cape Adare, a mean January temperature of slightly over 32° was obtained on one expedition, under abnormally favourable conditions.

greeable character of Antarctic exploration. They prevent much melting of snow and ice, and are monotonous and depressing. The mean annual temperatures experienced have been in the vicinity of 10°–15°, and the minima of an ordinary Antarctic winter go down to — 40° and below, but so far no minima of the severest Siberian intensity have been noted. The British expedition on the *Discovery* recorded — 67.7° at Cape Armitage at noon, May 16, 1903, and also noted — 40° in midsummer. The maxima have varied between about 35° and 50°.

The temperatures at the south pole itself furnish an interesting subject for speculation. It is likely that near the south pole will prove to be the coldest point on the earth's surface for the year, as the distribution of insolation would imply, and as the conditions of land and ice and snow there would suggest. There is, however, room for doubt whether the lowest mean annual temperature will be at the mathematical pole. It is almost certain that the lowest winter and summer temperatures in the southern hemisphere will be found in the immediate vicinity of the pole. One attempt to draw isotherms for the Antarctic zone, on the basis of the recent data, is that of Passerat, who has charted the mean winter and mean summer temperatures. Obviously these charts are based on extremely incomplete data, and can only be regarded at best as tentative in the highest degree. On the mean winter chart, the isotherm of — 4° (— 20° C.) is mostly within the Antarctic circle, and

in places well within it, while $-13°$ ($-25°$ C.) appears between lats. 70° and 80° on Graham Land and Victoria Land. On the mean summer chart the isotherm of 32° (0° C.) is about half within and half without the Antarctic circle, and partly within lat. 70°. The isotherm of 23° ($-5°$ C.) appears on Victoria Land, between lats. 70° and 80°. Krebs has attempted to draw isotherms for the far southern latitudes, using the data collected during the years 1901–1904. The isotherms on the mean annual isothermal chart of the world given in Hann's *Lehrbuch der Meteorologie* have been extended to include latitudes up to 80° S. The lowest temperature shown is indicated by portions of the isotherm of $-4°$ at about latitude 80° S.

It must not be supposed that the isotherms in the Antarctic region run parallel with the latitude lines. They bend polewards and equatorwards at different meridians, although much less than in the Arctic.

The annual march of temperature in the north polar zone, for which we have the best comparable data, is peculiar in having a much-retarded minimum, in February or even in March—the result of the long, cold winter. The temperature rises rapidly towards summer, and reaches a maximum in July. Autumn is warmer than spring. Winter comes on gradually, the summer slowly "falling asleep." The polar type of annual march of temperature is illustrated in the accompanying curves (See Fig. 33.).

The continents do not penetrate far enough into

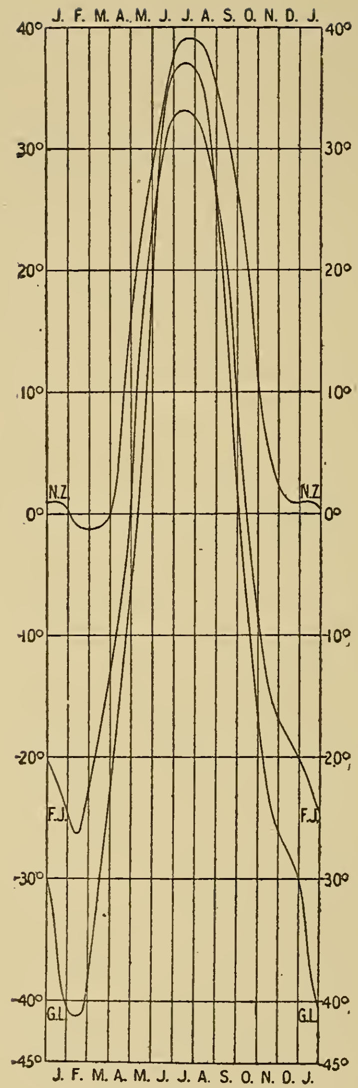

Fig. 33. Annual March of Temperature: Polar Type

N. Z., Novaya Zemlya. F. J., Franz Joseph's Land. G. L. Grinnell Land.

the Arctic zone to develop a pure continental climate in the highest latitudes. Verkhoyansk, in lat. 67° 6′ N., almost on the Arctic circle, furnishes an excellent example of an exaggerated continental type for the margin of the zone, with an annual range of 120°. One-third as large a range is found on Novaya Zemlya. The diurnal period of temperature is noted during the time when the sun is visible, but is hardly, or not at all, perceptible during the dark season. During the latter, according to the *Fram* observations, the day hours are usually colder than the night hours. This appears to be an effect of winds, for colder, northerly winds prevailed during the hours of daytime, and milder, southerly winds by night. Polar climate as a whole has large annual and small diurnal ranges, but sudden changes of wind may cause marked irregular temperature changes within twenty-four hours, especially in winter. The small ranges are associated with greater cloudiness, and *vice versa*. The mean diurnal variability is very small in summer, and reaches its maximum in winter, about 7° in February, according to Mohn.

Pressure and Winds. Owing to the more symmetrical distribution of land and water in the southern than in the northern polar area, the pressures and winds have a simpler arrangement in the former, and may be first considered. Recent Antarctic exploration has considerably modified some of the views which have been held regarding the general winds of the south polar area, and their controlling pressures.

The rapid southward decrease of pressure, which is so marked a feature of the higher latitudes of the southern hemisphere on the isobaric charts of the world, does not continue all the way to the south pole. Nor do the prevailing westerly winds, constituting the "circumpolar whirl," which are so well developed over the southern portions of the southern hemisphere oceans, blow all the way home to the south pole. The steep poleward pressure gradients of these southern oceans end in a trough of low pressure, girdling the earth at about the Antarctic circle. From here the pressure increases again towards the south pole, where a permanent inner polar anticyclonic area is found, with outflowing winds deflected by the earth's rotation into easterly and south-easterly directions. A chart of the south polar isobars for February (after Sir John Murray and Dr. Buchan), published in 1898, showed a pressure of 29.00 inches in the low pressure girdle, and the isobar of 29.50 inches around the inner polar area. These easterly winds have been observed by the recent expeditions which have penetrated far enough south to cross the low pressure trough. The limits between the prevailing westerlies and the outflowing winds from the pole ("easterlies") vary with the longitude and migrate with the seasons. The change in passing from one wind system to the other is easily observed. The *Belgica,* for example, in lats. 69½°–71½° S., and longs. 81°–95° W., was carried towards the west by the easterly winds in summer, and in winter was

driven east by the westerlies, and then again to the west. The *Belgica* thus lay in winter on the equatorial, and in summer on the polar side of the trough of low pressure. The seasonal change in wind direction was very marked, being almost monsoon-like in character. On the other hand, the English expedition at lat. 77° 50′ S. was persistently on the polar side of the trough, with dominant S., S.E., and E. winds. The smoke from Mt. Erebus, however, showed prevailing south-westerly currents. The German expedition on the *Gauss* was also under the régime of the easterly winds during its stay in winter quarters. The *Belgica* had fewer calms than some stations nearer the pole. The south polar anticyclone, with its surrounding low pressure girdle, migrates with the season, the centre apparently shifting polewards in summer and towards the eastern hemisphere in winter. The cloudier winds are poleward; the clearer winds blow out from the pole. The outflowing winds from the polar anticyclone sweep down across the inland ice and are usually cold. Under certain topographic conditions, descending across mountain ranges, as in the case of the Admiralty Range in Victoria Land, these winds may develop high velocity and take on typical foehn characteristics, raising the temperature to an unusually high degree. From the fact that certain warm, southerly winds have been reported from the mountainous eastern coast of Victoria Land as being damp and snow-laden, Sir Clements Markham has suggested

that they come from an open ocean, beyond the south pole. Foehn winds have been noted in the South Orkneys, from W.N.W. They are also known on both coasts of Greenland, when a passing cyclonic depression draws the air down from the icy interior. These Greenland foehn winds are important climatic elements, for they blow down warm and dry, raising the temperature even 30° or 40° above the winter mean, and melting the snow.

In the Arctic area the wind systems are less clearly defined, and the pressure distribution is much less regular, on account of the irregular distribution of land and water. The isobaric charts published in the report of the Nansen Expedition show that the North Atlantic low pressure area is more or less well developed in all months. Except in June, when it lies over southern Greenland, this tongue-shaped trough of low pressure lies in Davis Strait, to the south-west or west of Iceland, and over the Norwegian Sea. In winter it greatly extends its limits farther east into the inner Arctic Ocean, to the north of Russia and Siberia. Between May and August it is much less well developed. The Pacific minimum of pressure is found south of Bering Strait and in Alaska. Between these two regions of lower pressure, the divide extends from North America to eastern Siberia. This divide has been called by Supan the "*Arktische Windscheide.*" High pressures are found in North America and in Siberia from September to March, the maxima being in Asia. The belt of somewhat

lower pressure connecting these two maxima is situated between Bering Strait and the north pole. In July and August the maximum pressure is between Greenland and somewhat east of Spitzbergen. The pressure gradients are steepest in winter. At the pole itself, pressure seems to be highest (about 30.079 ins.) in April, and lowest (29.882 ins.) from June to September. The annual range is therefore only about 0.20 in.

The prevailing westerlies, which in the high southern latitudes are so symmetrically developed, are interfered with to such an extent by the varying pressure controls over the northern continents and oceans, in summer and winter, that they are often hardly recognisable on the wind maps. The isobaric and wind charts prepared by Buchan show that on the whole the winds blow out from the inner polar basin, especially in winter and spring. During his last expedition, in the winter of 1905–06, Peary reports "every few days we had violent winds from the south—sometimes in the shape of squalls of a few hours' duration, sometimes continuing as furious gales for two or three days." During a westerly gale of six days' duration (lat. 85° 12′ N.) Peary and members of his party drifted some seventy miles to the eastward on the ice.

In the European and North American polar areas the annual march of pressure gives a spring maximum, in April and May, and a minimum in January or February. The daily fluctuations in pressure in

these circumpolar latitudes are about twice as large in winter as in summer.

Rain and Snow. Rainfall on the whole decreases steadily from equator to poles. The amount of precipitation must of necessity be comparatively slight in the polar zones (15-10 ins., and less), chiefly because of the small capacity of the air for water vapour at the low temperatures there prevailing; partly also because of the decrease, or absence, of local convectional storms and thunder-showers.[1] Even cyclonic storms cannot yield much precipitation. The polar zones, therefore, have a permanent deficiency of precipitation. Their deserts of snow and ice are climatic deserts in more senses than one. These extended snow and ice fields naturally tend to give an exaggerated idea of the actual amount of precipitation. It must be remembered, however, that evaporation is slow at low temperatures, and melting is not excessive. Hence the polar store of fallen snow is well preserved; interior snow fields, ice sheets, and glaciers are produced. Nansen is of the opinion that the amount of condensed vapour, much of it being in the form of "frozen fog" (hoar frost) and not readily measurable, exceeds evaporation in the polar districts.

The commonest form of precipitation is naturally snow, the summer limit of which, in the northern hemisphere, is near the Arctic circle, with the exception of Norway. In lat. 70° N., at Boothia Felix,

[1] Locally, under exceptional conditions, as in the case of the western coast of Norway, the rainfall is a good deal heavier.

40 per cent. of the precipitation from June to August comes in the form of snow. So far as exploration has yet gone into the highest latitudes, rain falls in summer, and it is doubtful whether there are places near sea-level where *all* the precipitation falls as snow. It is also uncertain whether any mountains reach a height where nothing but snow falls. Von Drygalski believes that the inland ice-cap of Greenland, over 2600 feet above sea-level, meets these conditions. Perhaps the interior of the south polar continent never has rain. The snow of the polar regions is characteristically fine and dry. Schwatka has pointed out that the snow huts of the Eskimos could not be built with the kind of snow that falls in the United States. At low polar temperatures *flakes* of snow are not found, but precipitation is in the form of ice spicules. The finest glittering ice needles ("diamond dust") often fill the air, even on clear days and in calm weather, and, gradually descending to the surface, slowly add to the depth of snow on the ground. Dry snow is also blown up from the snow-fields on windy days, interfering with the transparency of the air. Snowfalls at temperatures of — 40°, and even below, have been reported from eastern Siberian and Arctic stations. It is probable that under these conditions the air is warmer aloft.

Humidity, Cloudiness, and Fog. The absolute humidity must be low in polar latitudes, especially in winter, on account of the low temperatures. Relative humidity varies greatly, and very low readings

have often been recorded. Cloudiness seems to decrease somewhat towards the inner polar areas, after passing the belt of high cloudiness in the higher latitudes of the temperate zones (see table, p. 116). In the marine climates of high latitudes, the summer, which is the calmest season, has the maximum cloudiness; the winter, with more active wind movement, is clearer. The data and curve given below illustrate these conditions (see Fig. 34). The summer maximum is largely due to fogs, which are produced where warm, damp air is chilled by coming in contact with ice. They are formed over open waters, as among the Faroe Islands, for example, and open water spaces, in the midst of an ice-covered sea, are commonly detected at a distance by means of the " steam fog " which rises from them. Fogs are uncommon in winter, when they occur as radiation fogs, of no great thickness. The small winter cloudiness, which is reported also from the Antarctic zone, corresponds with the low absolute humidity and small precipitation. The coasts and islands bathed by the warm

ANNUAL MARCH OF CLOUDINESS IN POLAR LATITUDES. MARINE TYPE. (Seven stations. Lat. 70° N.)

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
7.1	6.9	6.4	7.0	7.7	8.3	8.5	8.2	8.0	8.0	6.8	6.6	7.5

waters of the Gulf Stream drift usually have a higher cloudiness in winter than in summer. The place of fog is in winter taken by the fine snow crystals, which often darken the air like fog when strong winds raise the dry snow from the surfaces on which it is lying.

As yet there is little detailed information concerning the cloud forms and movements in the polar zones, and the reports are rather confusing. The records of the Nansen Expedition show a greater cloudi-

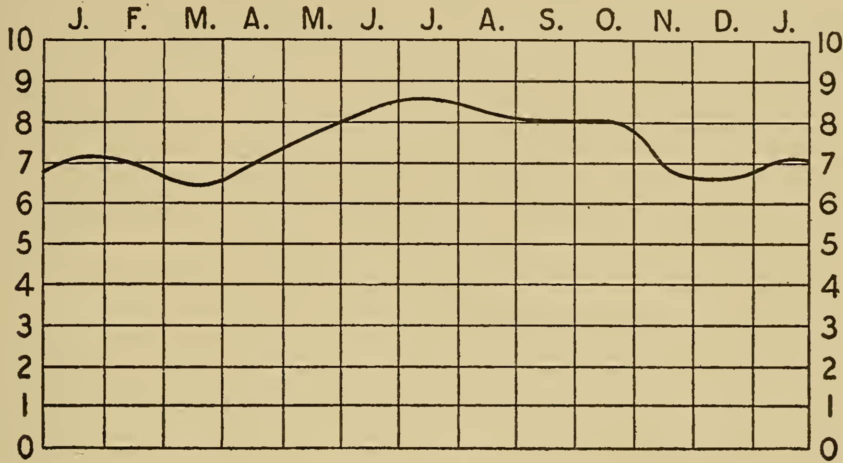

FIG. 34. ANNUAL MARCH OF CLOUDINESS IN THE NORTH POLAR ZONE: MARINE TYPE

ness by day, and with stronger winds. Cumulus forms are rare, even in summer, and it is doubtful whether this cloud occurs at all in its most typical development. Clearly defined cloud forms have been reported by some observers to be very rare indeed in the Arctic, especially in the winter sky. On the other hand, Lieutenant Royds, of the *Discovery*, reports that he never saw such striking and beautiful examples of every kind of cloud as within the Antarctic circle. At Griffith Island, in the north polar zone, two months passed without clouds. And " day after day, with glorious clear skies and continuous sunshine " is reported by the *Discovery* in the Antarctic.

Stratus is probably the commonest cloud of high latitudes, often covering the sky for days without a break. In place of well-developed cloud forms, the air is filled with fog in summer, which often grows into poorly defined stratus clouds. Cirrus cloud forms probably decrease polewards. At the South Orkneys, cirrus was observed at altitudes of 6000 to 8000 feet. Nansen's results give an average cloud movement from W.N.W. and N.W. In the Antarctic, Nordenskjöld reports cirrus from W. to W.S.W., and the *Belgica* expedition noted cirrus from the east in summer only.

Cyclones and Weather. The prevailing westerlies continue up into the margins of the polar zones. Many of their cyclonic storms—the weather controls of temperate latitudes—also continue on to the polar zones, giving sudden and irregular pressure and weather changes. The inner polar areas seem to be beyond the reach of frequent and violent cyclonic disturbance. Calms are more common; the weather is quieter and fairer; precipitation is less. Most of the observations thus far obtained from the Antarctic come from this marginal zone of great cyclonic activity, violent winds, and wet, disagreeable, inhospitable weather, and therefore do not show the features of the actual south polar climate.

The most thorough study of cyclonic movements in the highest latitudes is that in connection with the Nansen expedition in the *Fram*. During the three years of her drift, depressions passed on all sides of

her, with a preponderance on the west. The direction of progression averaged nearly due east, and the hourly velocity twenty-seven to thirty-four miles, which is about that in the United States. The rainy winds were usually S. and S.E., while N.E. and N.W. were least likely to bring rain or snow. For the higher latitudes, most of the cyclones must pass by on the equatorial side of the observer, giving "backing" winds in the northern hemisphere. The main cyclonic tracks are such that the wind characteristically backs in Iceland, and still more so in Jan Mayen and on the eastern coast of Greenland, these districts lying on the north and west of the path of progression. Frightful winter storms occasionally occur along the east coast of Greenland and off Spitzbergen. During the drift of the *Fram* the southerly winds were the warmest in winter and the northerly the coldest, showing that, at the 82d parallel of latitude, the Siberian cold pole ceases to have much influence.

For much of the year in the polar zones the diurnal control is weak or absent. The successive spells of stormy or of fine weather are wholly cyclonically controlled. Extraordinary records of storm and gale have been brought back from the far south and the far north. The Swedish Antarctic expedition, for example, under Nordenskjöld, in 1902–03, experienced for five months, beginning in May, a period of storms with short intermissions never exceeding three days, and during all of this period the average

wind velocity was twenty-three miles an hour, and for a fortnight it averaged forty-five miles. The *Discovery* reported a gale on July 19, 1902, which lasted ten hours with a velocity of eighty-five miles an hour. Wind direction and temperature vary in relation to the position of the cyclone. During the long, dreary winter night the temperature falls to very low readings. Snowstorms and gales alternate at irregular short intervals with calmer spells of more extreme cold and clear skies. The periods of greatest cold in winter are calm. A wind from any direction will bring a rise in temperature. This probably results from the fact that the cold is the result of local radiation, and a wind interferes with these conditions by importing higher temperatures, or by mixing upper and lower strata. During a northern polar winter the average thickness of ice formed over the oceans, where no storms or strong tides interfere, reaches six feet and more. Nansen found a thickness of over eight feet in one year. During the long summer days the temperature rises well above the winter mean, and under favourable conditions certain phenomena, such as the diurnal variation in wind velocity, for example, give evidence of the diurnal control. But the irregular cyclonic weather changes continue, in a modified form. There is no really warm season. Snow still falls frequently. The summer is essentially only a modified winter, from the point of view of temperate zone man, especially in the Antarctic, where accounts of low temperatures,

high winds, frequent fogs, and much cloud do not give a very cheerful picture of weather conditions. In summer, clear spells are relatively warm, and winds bring lower temperatures. In spite of its lack of high temperatures, the northern polar summer, near the margins of the zone, has many attractive qualities in its clean, pure, crisp, dry air, free from dust and impurities; its strong insolation; its slight precipitation. In certain places, as on the interior fjords of Greenland and on the tundras of Asia and North America, the summer brings swarms of gnats and flies, which are an extreme annoyance, and the prevalent summer fogs are a serious disadvantage.

Twilight and Optical Phenomena. The monotony and darkness of the polar night are decreased a good deal by the long twilight, due to the high degree of refraction at low temperatures. The sun actually appears and disappears some days before and after the times which are geometrically set. Light from moon and stars, and from the aurora, also relieves the darkness. Optical phenomena of great variety, beauty, and complexity are common. Solar and lunar haloes and coronas, and mock suns and moons are often seen. Auroras seem to be less common and less brilliant in the Antarctic than in the Arctic. Sunset and sunrise colours within the polar zones are described as being extraordinarily brilliant and impressive.

CHAPTER VII

THE HYGIENE OF THE ZONES

Introduction: Some General Relations of Climate and Health—A Complex Subject—Climate, Micro-organisms and Disease—Geographical Distribution of Disease—Tropics: General Physiological Effects—Tropical Death-rates—Hygiene in the Tropics—Tropical Diseases—Malaria—Yellow Fever—Dysentery—Diarrhœal Disorders—Tropical Abscess of the Liver—Cholera—Plague—Sunstroke and Related Conditions—Dengue—Beri-beri—Other Minor Diseases—General Conclusions: Tropics—Temperate Zones: General—Winter and Summer Diseases—Tuberculosis—Pneumonia—Diphtheria—Influenza—Bronchitis—Rheumatism—Measles and Scarlet Fever—Typhoid Fever—Whooping Cough—Cholera Infantum—Hay Fever—Polar Zones: General—Scurvy—Climate and Health: General Conclusions.

Introduction: Some General Relations of Climate and Health. From earliest times people have sought in atmospheric conditions an explanation of the occurrence of disease, and have often found in statistics of mortality and of weather a more or less striking parallelism. Many fairly obvious facts naturally point to some relation of cause and effect in this matter. Some diseases are found principally in the warmer climates; others seem to prefer the colder.

Some are usually more active in the warmer, or the drier, months; others have shown the contrary relation. High altitudes are free from some diseases which prevail near sea-level, and have certain favourable climatic characteristics long recognised in the treatment of disease. The pure air, increased respiration, and deeper breathing are stimulating and health-giving; they are beneficial in many affections of the lungs, although occasionally over-stimulating in nervous and cardiac troubles. In the case of other diseases, again, altitude has no effect. Dry climates, especially deserts, whose air is usually exceptionally pure and aseptic, are generally healthful, and are beneficial in many cases where mountain climates are too stimulating. The climates within forested areas have proved especially favourable in cases of phthisis. Ocean air, pure and dust-free, with its saline constituents and equability of temperature, is beneficial to most persons as a moderate tonic and as a restorative in many illnesses. Winds are important agents in promoting health. The cool, refreshing sea-breeze of the tropics brings in pure air from the sea, and is one of the most important desiderata in hot climates. Winds are active ventilating and purifying agents where population is congested. Fogs and clouds, by cutting off sunlight, weaken one of the best agents in promoting health, for the germicidal action of sunlight has been proved by many investigators. Sternberg has called it " one of the most potent and one of the cheapest agents for the destruction of patho-

genic bacteria," and says "its use for this purpose is to be recommended in making practical hygienic recommendations." In London, a higher death-rate after a long fog may, however, result from the lower temperature during the fog, and not from any direct effect of the fog itself.

A Complex Subject. Facts like the foregoing naturally prejudice one in favour of a causal connection between atmospheric conditions and disease. Nevertheless, such studies have often led to very contradictory conclusions. Diseases usually characteristic of one zone are known to spread widely over other zones. Diseases which usually prefer the warmer months sometimes occur in the coldest. Rules, previously determined as the result of careful investigation, often break down in a most perplexing way. Some of the difficulty in this lack of agreement results from untrustworthy statistics, often collected under very varying conditions and really not comparable. Curves are smoothed to such an extent that they can be made to show anything. Conclusions are drawn in individual cases which are neither of general application, nor do they even apply locally on any other occasion than the special one in question. Most of this disagreement comes from the fact that not only may the different weather elements themselves, temperature, moisture, wind, sunshine, and so on, each have some effect in the production of a disease, which it is impossible to determine, but so many other factors are concerned in the mat-

ter that confusion and contradiction in the conclusions reached are inevitable. Sanitation, food, water, habits, altitude, character and moisture of the soil, race, traffic, and other controls serve to complicate the problem still further. In most studies of climate and health some, or even many, of these factors have not received attention. Hence the results have usually been incomplete. Local, peculiar, and temporary conditions may play a large part in the prevalence of disease. Overcrowding under unhygienic conditions, especially indoors during cold weather, and traffic by rail, steam, caravan, or on foot, are often more important than climate. The frequent escape of mountain, of desert, and of polar peoples from epidemics is to be attributed in most cases to the smaller chance of importing disease because of little intercourse with the outside world, and of spreading it, when imported, because of the scattered population. It may be noted, however, that the crowding indoors and the sparseness of population in these two cases are more or less directly climatically controlled.

Climate, Micro-organisms and Disease. The cause of disease is now no longer sought directly in meteorological conditions, but in the effects, more or less direct, of these conditions upon the micro-organisms which are the specific cause of the disease. Atmospheric conditions may help or may retard the development of the micro-organism, and may strengthen or weaken the individual's power of resistance against the attacks of the germ, as well as

affect his susceptibility. Thus new views have replaced the old. Winds used to be regarded as the chief agents in spreading epidemics: now it is known that disease cannot be carried far by winds, for the micro-organisms do not long maintain their power in the free air and under the sun. Rain has been supposed directly to control the distribution of diseases: now we believe that precipitation acts only indirectly, through drinking water, or through its control of the dust in the air. Dust from dry soil may contain the germs of infectious diseases, and aggravates affections of the respiratory organs. Harmful exhalations are no longer believed to be given off by the soil, but the condition of the soil as to moisture and temperature may affect the development and diffusion of certain micro-organisms. Some parallelism has been discovered between the prevalence of certain diseases, such as diarrhœa and typhoid fever, and soil temperatures or the ground-water level.

Geographical Distribution of Disease. The scheme of classifying disease geographically, on a broad climatic basis, is attractive, but not very satisfactory. For, on the one hand, many diseases are practically universal in extent, showing great independence of climate, and on the other, the history of many diseases is still in the making. In the distribution of disease too many factors are concerned to make any simple and accurate treatment possible as yet. In spite of this complexity, however, certain broad general statements may be made, useful in enabling the

layman properly to co-ordinate his ideas on the subject, and fairly accurate within reasonable limits.

Tropics: General Physiological Effects. The uniformly high temperatures of the tropics, especially when combined with high humidity and the characteristically small diurnal variability of temperature, have certain fairly well established physiological effects. Among these the following are commonly noted: increased respiration; decreased pulse action; profuse perspiration; lessened activity of stomach and intestines, and tendency to digestive disorders; a depression of bodily and mental activity, enervation, indifference, disinclination to exertion,—in fact, a general, ill-defined condition of debility; increased activity of the liver; surexcitation of the kidneys. In damp, hot air, evaporation from lungs is slight; the blood becomes more diluted; there is a deficiency in the number of red corpuscles in consequence of the diminished proportion of oxygen in the air. There is less power to do work; greater fatigue from work; lowered vitality. All this renders the body less able to resist disease. An anæmic condition in the moist tropics is widespread.

Tropical Death-rates. As compared with the death-rates in colder latitudes, tropical death-rates average high. They range from the appalling rate of 483 per 1000 among European troops on the Gold Coast in 1829–1836, through 121 per 1000 for European troops in Jamaica in 1820–1836, down to so low a rate as 14.84 per 1000 for British troops in

India in 1896. These death-rates, however, represent such very diverse conditions of season, climate, race, occupation, soil, mode of life, food, dwelling, etc., that they cannot legitimately be compared with one another. The prevalence of some special disease in exceptionally virulent or widespread development will raise the death-rate of any year far beyond its usual figure. Again, the presence of some insect which causes loss of crops, and the resulting lowered vitality of the people in consequence of insufficient food, may easily swell the death-rate. Nor can these tropical death-rates properly be compared with the death-rates noted under different conditions in other latitudes. (A recent attempt to compare the death-rate among American troops in the Philippines with the general death-rate in certain American cities is an excellent example of the danger of comparing two totally different things). So various and so complex are the controlling factors that critical comparative study is not worth while. Tropical death-rates are certainly high, but this fact should not be attributed solely to the dangers of the climate. Bad sanitary conditions and lack of medical attendance account for many, if not most, of the high tropical death-rates among the natives; and an irrational mode of life explains many deaths among persons coming from cooler climates. Tropical death-rates are being reduced with remarkable rapidity in all countries which are wholly or partly under white control, and especially among European troops in the

tropics. This is the result of experience with tropical conditions, and of the increased precautions which are now taken in selecting and caring for the men.

Hygiene in the Tropics. Under the special conditions of tropical climates, the resident who comes from a cooler latitude needs to take special precautions regarding his mode of life and personal hygiene. A rational, temperate mode of life, especially the avoidance of alcoholic excess; regular exercise; non-fat-producing food; clothing suited to the climate, such as duck or linen for outside garments during the day, and light woollen for the cool of the evening and night; careful attention to the site and construction of dwellings; all possible sanitary precautions; keeping cool during the warmest hours and season by the use of fans or punkahs, by frequent baths, and by abstaining from hard work; protection against mosquitoes by means of screens; frequent change of climate by returning to cooler latitudes,—all these are important. It seems like a contradiction, but it is a fact, that the danger of taking cold in the tropics is very great, and must be carefully guarded against. General Wolseley is reported to have said of the tropics, "not to get cold is to avoid almost certainly all the causes of disease," and a recent writer has well said that these words should be inscribed on the walls of all barracks in the tropics. The situation may be summed up in the rule: "Respect the sun, and rain, and wind; clothe with a view to avoiding chill, and live temperately." The dan-

ger of becoming chilled is greatest during the cooler hours of evening and night, during rains, or when cool winds blow. The skin does not react well in the tropics, hence chills are frequent with even slight temperature changes, especially when there is wind. As to the best style of dwelling for the tropics, there is no absolute agreement. The material can best be determined by the local conditions in each case. Wood, stone, and thatch are employed successfully. Of whatever construction, houses should be roomy and airy, and protected against direct sunshine during the hottest hours of the day.

Tropical Diseases. In addition to the physiological effects just considered, certain diseases are so much at home in the tropics that they have come to be known as *tropical diseases*. This designation, however, as Sir Patrick Manson uses it in the title of his famous work, does not mean diseases confined to the tropics, but is employed in a meteorological sense for diseases associated with, but not solely or even directly due to, high temperatures. Tropical climatic conditions, *per se,* probably do not injuriously affect the natives of the tropics any more than do the conditions of extra-tropical climates affect those who live in them.

Sir Patrick Manson has made the fact very clear that the difference between the diseases of tropical and extra-tropical latitudes lies in the specific cause of these diseases. For the development of certain disease germs, certain temperatures are required.

Sometimes the temperature is too high; sometimes too low. Again, certain media are necessary in propagating certain diseases, as *e. g.,* a third organism, other than the disease germ itself, and man, who has the disease. The third organism may be a tropical species, as in the case of the tsetse fly; if so, the disease is a tropical disease. The opportunity for contracting the disease is best, or exists solely, in the tropics. Again, some diseases are the result of toxins generated by germs living in an external medium. One condition of development of these germs may be a certain high temperature. Thus the disease is a tropical disease, *e. g.,* beri-beri. On the other hand, when everything seems favourable, natural enemies of the germs themselves, or of the organism which subtends the germs, may destroy them. Dr. Manson's conclusion, which is the result of careful study, may well be accepted as an authoritative statement. "The more we learn about these diseases, the less important in its bearing on their geographic distribution, and as a direct pathogenic agency, becomes the *rôle* of temperature *per se,* and the more the influence of the tropical fauna."

Besides the more or less direct effects of exposure to tropical sun and heat, such as sunstroke, heat exhaustion, and the like, there are malaria, in varied forms, and dysentery, the two worst enemies of white residents in the tropics; dengue; ulcers; yaws; tropical abscess of the liver, a common and dreaded disease; diseases like yellow fever, cholera, and plague,

which are more or less limited to certain localities, and are being hemmed in more and more by modern sanitary measures; many other infectious diseases which are common to colder as well as warmer latitudes; and beri-beri, elephantiasis, and other diseases which attack the coloured race chiefly, and are therefore of a medical rather than of a practical interest to white people. The fact that plague, and leprosy, and to some extent cholera as well, are practically limited to the tropics, is the result of modern sanitary precautions in the extra-tropics. The unsanitary conditions among tropical peoples favour the spread of these and similar diseases, and not the climate *per se*. Nevertheless it is as clear as day, in the words of Dr. Manson, that these very unsanitary conditions are "more or less an indirect outcome of tropical climate." There is a greater variety in tropical than in extra-tropical diseases, but then many diseases common in cooler latitudes prevail also near the equator, and many diseases prevail near the equator which have practically been banished from higher latitudes. Tropical climate is not the sole, or even in many cases the determining factor. Most tropical diseases attack both natives and whites; sometimes the former suffer most; sometimes the latter. There is no rigid rule; but the racial element is often very potent.

Malaria. Malaria, next to tuberculosis one of the most important of diseases, was formerly considered a poisonous, gaseous emanation from the soil. It is

now known to be a germ disease. In 1880, Laveran, a French army surgeon in Algiers, discovered a parasite in the blood of malarious persons. Manson later suspected mosquitoes as the means of propagating the malarial parasite. (Dr. A. F. A. King, of Washington, D. C., had advanced a similar suggestion in 1841.) Ross, at Manson's suggestion in 1894, followed up the clue in India, and established the fact. His work, and that of Grassi, Koch, and others, has shown that the insect here concerned is a mosquito of the single genus *Anopheles,* and that malaria is due mainly, if not solely, to the injection of the parasites into the blood of human beings by the bite of mosquitoes previously infected by stinging some human being suffering from malaria.

Malaria is very widely distributed, from the polar circles to the equator, but the endemic foci, Manson points out, tend to become more numerous towards the equator. There is, on the whole, a fairly regular decrease in frequency and in severity from equator poleward. In certain parts of the tropics, as, for example, the Gold Coast, the mouths of the Congo and Zambesi, New Guinea, etc., malaria is so prevalent and so severe that the question of residence there for the white race has been practically controlled thereby. The disease is commonly associated with swamps, and moist low-lying districts, while uplands and well-drained areas are usually less affected. This relation, however, seems to be somewhat less apparent in the tropics than in higher latitudes. Malaria

is perennial in the tropics, with a general tendency to a maximum in the warmer or rainy season. In the temperate zone the maximum is in late summer or early autumn.

It is clear, with the mosquito theory so well established that Koch can say, of tropical Africa, "where there are mosquitoes there is malaria, and where there are no mosquitoes there is no malaria," that the older views regarding the relation of climate and soil to malaria must have undergone some change. Nevertheless, there is still a fairly definite relation of cause and effect in this matter. For the development of the malarial parasite in the body of the mosquito a certain degree of heat is necessary, probably a mean temperature of at least 60° F. Hirsch pointed out, some years ago, that 60° F. is the limit at which malarial fevers can occur. Hence it happens that the same mosquito may be harmless at low temperatures and dangerous at higher. Rainfall is important because the malaria-bearing mosquito passes part of its life in water. Hence lakes, and especially marshes, pools, and swamps are critical controls as breeding-places of the mosquitoes. Rain thus differs in its effects according to the amount of precipitation, and according to the conditions present where the rain falls. A rain which in one place floods and scours out mosquito-breeding pools, in another may just suffice to fill hollows and low-lying places where mosquitoes may then breed. Digging up the soil, whether for the first time or not, may result in hol-

lows where puddles and pools may collect, and thus give rise to malaria. The ground-water level, by affecting soil-moisture, also plays a part, but decomposing vegetable matter is no longer believed to be an essential. Many occurrences or non-occurrences of malaria, unexplained on any meteorological grounds, may be ascribed to the presence or absence of the malaria-bearing mosquito.

The best prevention of malaria is to screen persons who have the disease, so that they cannot infect mosquitoes, and to screen all doors and windows so that healthy individuals may not be bitten by infected mosquitoes. Wholesale protection of this kind has recently been attempted in Havana, on the Isthmus of Panama, in West Africa, and elsewhere. The danger of being bitten by the *Anopheles,* whose habits are chiefly nocturnal, is greatest at night, but residence in tropical malarial districts for white persons is always safest away from native huts and villages. The draining and filling up of swamps, pools, and puddles; levelling of the surface of the ground; cultivation of the soil by planting trees or other forms of vegetation; destruction of the larvæ by pouring oil on the standing waters; location of dwellings on high, dry sites; having these dwellings properly screened,—all these precautions should be taken. Further, a rational and scientific use of quinine, and a change of climate to a higher latitude, are both very important measures in case of the contraction of the disease. Residence at an altitude of a few thousand

feet, where the temperature is lower than at sea-level, is usually a sure preventive, but the mountain climates may be injurious to persons suffering from heart or lung troubles, or from rheumatism.

Relapses are very common after a malarial attack, and an anæmic condition may continue for a long time. According to Koch, these relapsing cases infect the new mosquitoes each spring, but the same authority believes it possible to destroy all the parasites in such cases, before the spring comes, by the use of quinine.

Malaria is one of the greatest obstacles in the way of white occupation of many tropical countries. Ross spoke well when he said that the success of imperialism depends largely on success with the microscope. The hope for the future lies in the determined effort to destroy the malaria-bearing mosquitoes, and to protect individuals from infection by these mosquitoes. Preventable, to a large extent, malaria certainly is, but it is beyond the range of human power to eradicate the disease, certainly within any time which is of present political interest. In the light of the new discoveries, however, white residents in the tropics are now in far less danger from malarial infection than they were a few years ago.

Yellow Fever. Yellow fever is endemic only on the eastern coast of the Americas, and on the western coast of Africa, chiefly within the tropics, although it frequently extends beyond them, as an epidemic, even to latitudes between 40° and 50°. It frequents

especially the squalid quarters of seacoast towns and the shores of large navigable rivers, readily following railways, canals, and other highways of travel. The opening of the Panama Canal and the establishment of new steamship lines between Central America and the Hawaiian and Samoan Islands, where no yellow fever has occurred, may easily be followed by the introduction of the disease into those islands. Within the tropics the rainy season brings the maximum prevalence of the disease; in extra-tropical latitudes, the summer and autumn. Hirsch asserts that it has not gained a foothold at temperatures below 68° F. Manson states that a temperature over 75° F. is needed for its development in epidemic form. Yellow fever weakens as cold weather approaches, and epidemics disappear when the temperature reaches 32° F., although the vitality of the germ may not be extinguished by frost (Manson). Stations more than a few hundred, or thousand, feet above sea-level are free from the disease, probably because of their lower temperatures. The altitude of this zone varies, but at the maximum, yellow fever has only very rarely occurred as high as 4000 feet above sea-level.

The actual cause of yellow fever is still unknown. The brilliant work of Reed, Carroll, Agramonte, and Guiteras has shown that the intermediate host, and the diffusing agent of the yellow fever parasite is a mosquito of the genus *Stegomyia fasciata,* which has previously been infected by biting a person suffering

from yellow fever. The disease is non-contagious where *S. fasciata* is not present, as at Petropolis, near Rio de Janeiro. Vigorous campaigns against the mosquito have recently produced a remarkable decrease of the disease at Havana, on the Isthmus of Panama, and at New Orleans in 1905. The endemic character of yellow fever in Rio is believed by Manson to be kept up by the continual arrival of foreigners who are susceptible to the disease. Newcomers are chiefly attacked. After one attack, immunity is usually secured. Persons who have lived for some time in endemic areas without having the fever are more or less exempt, or may have the disease in mild form. The immunity of natives who leave their home decreases with the length of their absence. Negroes enjoy comparative immunity; the yellow race is more, and the white race most, susceptible. Of the white race, northerners are more susceptible than southerners.

Dysentery: Diarrhœal Disorders. Dysentery occurs epidemically in all latitudes, but has its home in the warmer climates, as a whole increasing in severity and frequency with approach to the equator. Some form of dysentery is almost always present in lower latitudes, where this disease is next in importance to malaria in causing high death-rates and in its lasting effects. High temperatures are clearly necessary for the development of the disease germ, but numerous other controls are also needed. The maximum is usually in the hottest, or wettest, months; cooler

weather checks the disease. In India, the latter half of the rainy season shows the maximum. Altitude cannot be relied on to give relief from dysentery; residents on mountains often suffer more than those at lower levels. Lack of sanitary precautions, impure water, overcrowding, poor food, excesses of all kinds, are predisposing causes. The best preventive is a rational, temperate mode of life; protection of the more susceptible parts of the body against chills, and a proper regulation of the whole system. Epidemics of dysentery seem independent of the effects of wind, rain, and atmospheric humidity. Immunity is not secured after one attack, several attacks being common.

In extra-tropical latitudes, diarrhœal disorders show a similar dependence on temperature, for they are most frequent in summer and early autumn. Usually the hotter the summer, the greater the prevalence and the severity of these complaints, and the higher the death-rate from them. Other factors are, however, concerned in this matter, so that "all attempts to express the diarrhœal mortality of a given place as a function of the temperature only have failed." Soil temperature is one factor between which and the death-rate from diarrhœal disorders some relation has been made out.

Tropical Abscess of the Liver. Rare in temperate and cool climates, tropical abscess of the liver, as the name implies, is mainly a disease of warmer latitudes and usually accompanies or follows dysentery.

Among the predisposing causes the most potent are injudicious and intemperate habits, especially overeating and over-indulgence in alcoholic beverages; insufficient exercise; exposure; chills, and in general the "congestive and degenerative conditions incidental to tropical life." Heat, malaria, and dysentery are active precursors of liver abscess, in that they lower the vitality. The disease is most common during the colder or rainier season, when chills are most frequent, but temperature is not the sole control. The physiological adjustment of a person from a colder latitude to tropical conditions of climate throws a considerable strain upon the liver. The result, especially if intemperate living is indulged in, is likely to be liver abscess. Chiefly because of their disregard of proper hygiene, white men and women are generally more liable to have the disease than natives; the death-rate among white troops in the tropics is much higher than among native troops in the case of this disease. Tropical liver abscess is most, but by no means solely, to be expected in the earlier years of residence in the tropics. Persons suffering from the disease should, if possible, be sent to a temperate climate, although there are many cases of recovery even in the tropics.

Cholera. Cholera is due to the specific microbe, the *comma bacillus,* discovered by Koch in 1883. From its home in India, it has spread in great waves as an epidemic over most of the globe, the last advance reaching its maximum extension early in the

decade 1890–1900, in northern Europe. Cholera has gone as far north as Bergen in Norway, and in Siberia up to about latitude 60° N. No general relations can be established between the occurrence of cholera and climatic or weather conditions. Local conditions exercise an important control. In higher latitudes, however, cholera seems most frequent towards autumn, decreasing with falling temperatures. Cholera is chiefly prevalent in low-lying places, on river banks, and where human beings are overcrowded under unsanitary conditions. The atmosphere is clearly not the agent for carrying the bacillus, for the latter does not keep its morbific character long in the free air. The principal agent in spreading the disease is traffic; but drinking-water certainly also plays a part. As a whole, cholera is rarer and milder in the higher latitudes, and has decreased in Europe in cold weather, coming up again in summer. It has, however, also been active at low temperatures. With many exceptions, there may be said to be a decrease with altitude, and soil moisture may also play a part.

Plague. The specific cause of plague is a bacillus discovered by Kitasato, a pupil of Koch, in 1894, and also independently by Yersin. Formerly very widespread, plague is now confined to the sub-tropical districts of southern Asia and of the Mediterranean. It has become a disease of warm climates, because it depends upon the unsanitary conditions in which tropical natives live, and it attacks the poorer part of

the population. Filth, famine, social misery, and overcrowding are predisposing causes. The conclusions regarding the relation of plague to weather and climate are almost as numerous as are those who have investigated this subject, but it is clear that plague is not limited by isotherms, and that meteorological conditions do not spread it, or solely control it. The Indian Plague Commission concludes that there is no direct connection between plague and climate; Hirsch had previously stated that the relation is unsettled. In the tropics, however, the disease has, on the whole, had a cool season, and in higher latitudes a warm season, maximum. As to altitude, plague has occurred at high levels in cold, dry climates, and at low levels where the climate is warm and moist. It has prevailed when the temperatures were so low that people suffered with the cold (Roumelia, 1737–8), and at temperatures so high that sunstrokes occurred (Smyrna, 1735). On the whole, plague has chiefly prevailed under moderately high temperature and moisture conditions, and where the soil is damp and the ground low. These facts do not, however, necessarily point to cause and effect.

The best preventives of plague are pure air and modern sanitation. In India, Haffkine has been very successful with inoculation. Plague travels by trade routes. Persons sick with, or incubating plague, and infected clothing and personal effects, carry the infection.

Sunstroke and Related Conditions. Several disagreeable and some fatal results of heat and humidity, not to be classed as diseases, are common in the tropics, and to a considerable extent also in extra-tropical latitudes, even as far as latitude 50° to 60° N. Sunstroke and heat prostration are most common in the tropics when the air is damp during calms, and in temperate latitudes during the hottest spells of summer, when the weather conditions are tropical in character. The germ origin of sunstroke has been maintained by Sambon, but the cause is to be found in the effects of insolation, direct and reflected; the air temperatures, and the undue heating of the body. The skin of white persons when exposed to the sun in the tropics often becomes burned and blistered, and travellers commonly suffer because of lack of protection of neck or limbs under sunshine. Exposure to the sun does not always explain sunstroke, for at sea the tropical sun is less fatal than on land,[1] and places with apparently similar conditions of insolation differ much as regards the prevalence of sunstroke. A great deal doubtless depends on occupation. Many forms of heat exhaustion are induced by exposure to high temperatures, but greatly aggravated by unsuitable clothing, impaired physical condition, and intemperance.

A study of the sunstroke weather of August, 1896, in the United States, led Dr. W. F. R. Phillips

[1] Stokers and firemen suffer from prostration on steamers in the tropics, but here artificial heat is partly responsible.

to conclude that the number of sunstrokes followed the excess of the temperature above the normal more closely than it did any other meteorological element; that there was no definite relation to the relative or absolute humidity; and that the liability to sunstroke increased in proportion as the mean temperature of any day approached the normal maximum temperature for that day.

Sunstroke is most common among those who are exposed to the sun, and at hard work under conditions which retard or check the cooling of the body by radiation or conduction. The best protection against sunstroke and heat prostration in general, and especially in the tropics, is to be found in the use of suitable light and loose clothing; loose, wide-brimmed, and well-ventilated headgear; avoidance of exposure to sun and to high temperatures in general; the use of a white umbrella; avoidance of alcohol and of an excess of heating foods, and in a temperate life in all respects. Poor health, fatigue, and violent exercise are all predisposing causes. Tropical camps should be located in cool and well-ventilated places, and tents should have double roofs.

Dengue. Dengue is a "highly infectious, febrile disease, characterised by severe rheumatoid pains in joints and limbs, and in some cases by a cutaneous eruption of varying character and duration." It is distinctly a disease of warm climates, although it has occurred as far north as latitude 40° in Europe and in North America, and as far south as the southern

tropic. It comes mostly in the hottest months, and is almost always checked by cold weather. Moisture has a subordinate influence. Dengue resembles yellow fever in its prevailing preference for coasts, deltas, and large river valleys; in its relation to overcrowding and unsanitary conditions, and in its advance along routes of travel. Dengue attacks any race, and immunity is not secured by one attack. There is often a recurrence.

Beri-beri. A dropsical affection, combined with a disturbance of motion and sensation, and of heart action, beri-beri is found principally in or near the tropics, being especially common in the Malay Peninsula, and the adjacent archipelago, where it is often a scourge. It is especially liable to break out among gangs of labourers. Beri-beri epidemics are most common during the rainy season. High temperature and dampness are controlling factors, as are poor health, fatigue, privation, chill, overcrowding, etc. Damp years are apt to be marked by the severity and prevalence of beri-beri.

Other Minor Diseases. Among the minor tropical diseases may be named sleeping sickness, limited to tropical Africa and almost wholly confined to the negro; and yaws, also distinctly tropical in distribution, requiring high temperature and moisture, found chiefly in some of the larger island groups, and principally affecting the negro.

General Conclusions: Tropics. All parts of the equatorial zone are not equally disagreeable or hostile,

so far as occupation by the white race is concerned. Many elderly persons and those who are overworked may find rest from nervous tension in the enervating climate of the tropics. The drier districts are to be preferred to the moister, the higher altitudes to the lowlands, coasts and islands well ventilated by prevailing winds, to regions where the air is stagnant. Much-needed relief from the heat at sea-level may be obtained by resort to tropical mountain stations, and many of these have become well-known health resorts. Tropical mountain climates resemble the climate of the temperate zones in their lower temperatures and in certain other ways, but they can never be the equivalent of a temperate zone climate, for they lack the seasonal changes. Some tropical climatic characteristics disappear with altitude, while others change little. The non-seasonal character of tropical mountain climates, the so-called "perpetual spring," is not by any means the best fitted for man's physical and mental development, however pleasant it may be for a time. With increase of altitude, there is a decrease in, or a disappearance of, some of the diseases which prevail near sea-level, such as malaria, yellow fever, liver abscess, etc. When introduced from the lowlands, such diseases are not likely to be severe, or to spread. In their stead, however, may come an increasing frequency of diseases which are characteristic of high latitudes, such as rheumatism, and heart and lung troubles. Tropical hill stations in India show a smaller mortality among the troops

than do lower levels. In India, as elsewhere in the tropics, hill stations are beneficial in restoring those who are exhausted by overwork or by the heat of the lowlands. They are especially advantageous for delicate women and children. Nevertheless, climates which are temperate because of altitude in the tropics cannot replace climates which are "temperate" because of latitude.

The acclimatisation of the white race in the tropics is a question of vast importance. Upon it depend the control, government, and utilisation of the tropics. It is a very complex problem, and it has been much discussed. It is complicated by the controls exercised by race, diet, occupations, habits of life, and the like. To discuss it fully is impossible in this place. The gist of the matter is this: White residents from cooler latitudes on coming into the tropics must adjust themselves physiologically to the new climatic conditions. During this adjustment there is more or less strain on various organs of the body. The strain may be too severe; then the individual suffers. The adjustment is usually much retarded and hindered by a persistence in habits of food, drink, and general mode of life which, however well suited to the home climate, do not fit tropical conditions. During the adjustment, especially if complicated by irrational habits, the body is naturally sensitive to the new diseases to which it is exposed. Even should no specific disease be contracted, there are anæmic tendencies and other degenerative changes. Experience teaches

that white men cannot with impunity do hard manual labour under a tropical sun, but that they may enjoy fairly good health as overseers, or at indoor work, if they take reasonable precautions. Acclimatisation in the full sense of having white men and women living for successive generations in the tropics, and reproducing their kind without physical, mental, and moral degeneration,—*i. e.,* colonisation in the true sense,—is impossible. Tropical disease and death-rates, as has been abundantly shown, can be much reduced by proper attention to sanitary laws, so that these rates may be not much, if any, higher than those in the extra-tropics. And with increasing medical knowledge of the nature and prevention of tropical diseases, as well as by means of modern sanitary methods, a white resident in the tropics will constantly become better able to withstand disease. As Manson has put it, acclimatisation is less "an unconscious adaptation of the physiology of the individual" than "an intelligent adaptation of his habits." For greater comfort, for better health, and for greater success, properly selected hill stations will, however, always be essential to northerners who have to live in the tropics, especially to white women and children.

It has been well said that the white soldier in the tropics is "always in campaign; if not against the enemy, at least against the climate." This sentence may be made to fit the case of the white civilian in the tropics by making it read: the white race in the

tropics is always in campaign against its enemy, the climate.

Temperate Zones: General. Far from being temperate as regards the general climatic conditions over much of the land area of the so-called temperate zones, these belts rightly deserve their name only in the sense that in their physiological effects they are intermediate between the equatorial and the polar zones. In the temperate zones the organs of the body act more equally than in the warmer or the cooler latitudes. In the central part of the temperate zones, especially over the continents, are found the four seasons. The winter cold is met by means of warm clothing, heated houses, and other means of protection. Unless too severe, or too prolonged, when deaths by freezing may occur, the cold of a continental winter in the north temperate zone acts as a healthful stimulant upon body and mind. In the tropics, the body is unused to adjusting itself to temperature changes, because such changes are there slight, and is readily affected by them. But the frequent, sudden, and severe changes of many parts of the temperate zone are usually borne without serious discomfort or injury, if the body is in good health, and is accustomed to adjusting itself readily to these changes. The habit of keeping houses very warm during the winter, and of having the air indoors very dry, weakens the body's power to resist the great cold outdoors, especially if the air be damp, and causes affections of throat, lungs, and nose. The summers,

although hot in the lower latitudes of these zones, and marked by spells of warm weather even to their polar limits, are not characterised by such steady, uniformly moist heat as is typical of the tropics. When the heat is extreme, and the relative humidity is high, night and day, sunstroke and kindred affections are occasionally noted in places, but the invigorating cool of autumn and winter are never far off, and may always be trusted to bring relief.

Winter and Summer Diseases. It is natural that marked seasonal and sudden weather changes, such as those which characterise much of the temperate zones, especially in the northern hemisphere, should be reflected in the character, distribution, and frequency of the diseases which are found in these zones. Diseases of the respiratory system, bronchial and rheumatic affections, diseases that result from colds and chills, pneumonia, bronchitis, influenza, diphtheria, whooping cough, are all common in climates with sudden marked temperature changes, especially if those changes are accompanied by cold, damp winds. These diseases are also most frequent in the winter months, when the weather changes are more common and more severe, and when, in consequence, the vitality of the body is lowered and its power of resistance against the attack of disease germs is weakened. A greater prevalence of diseases of the respiratory organs, catarrhs, and rheumatic affections in cool, moist weather, with sudden changes, has been shown by

Weber, and several investigators have found a higher mortality after a greater variability of temperature. Many contagious or infectious diseases, such as diphtheria, influenza, measles, and scarlet fever, for example, are also more common in the colder season, not because the lower temperatures are the direct controlling factor, but largely because the colder weather drives people indoors; houses and buildings generally are less well ventilated; more clothing is worn, less attention is paid to personal cleanliness, and there is increased opportunity for contagion, especially among the poorer classes. Obviously, these are indirect effects of meteorological conditions. Other factors, also, must be taken into consideration. Thus one reason why the natives of the farther north, where the winters are very severe, suffer less from some of the diseases which are common in warmer latitudes is not because of the lower temperatures, but because they are less exposed to contagion owing to less communication with the outside world.

In the warmer months, fevers and diseases of the digestive system, diarrhœa, malaria, typhoid fever, are prevalent. Thus there are usually two maxima of mortality: one in the colder season, when the variability of temperature is greatest, chiefly due to respiratory diseases, and another in the warmer months, largely due to infant mortality from diarrhœal disorders.

Tuberculosis. "A nationally self-inflicted, unnecessary, and preventable pestilence"; world-wide

in extent; found in every variety of climate, and at all altitudes; causing from 10 to 15 per cent. of all deaths; the scourge of the temperate zone, tuberculosis is, on the whole, less frequent in higher latitudes, on mountains, and in arid or semi-arid districts. Climate, however, is not the controlling factor in the latter cases, but sparseness of population and infrequency of communication with the outside world. The density of population; the social and economic conditions; the occupations and habits of the people,—these are important controls. Overcrowding amid unsanitary surroundings, absence of sunlight, impure air, are predisposing causes. Weather, or other conditions which decrease the vitality, increase the susceptibility to tuberculosis. Sudden temperature changes, especially with high relative humidity at low temperatures, cause chills and lower vitality.

Consumption, it is clear, can be successfully treated where pure air, abundant sunshine, good food, and outdoor exercise are to be had. The first of these desiderata, pure air, and plenty of it, is the most important of all. It is usually found on desert, ocean, mountain, and in forest. Hence such climates are generally advantageous in the treatment of tuberculosis of various kinds. Yet climate is no longer believed to play as important a *rôle* in the matter as was formerly assigned to it. Good hygiene has to a large extent replaced climate. A health resort

where a patient can find comfortable quarters, congenial company, plenty of diversion, and where favourable climatic conditions, such as abundant sunshine, absence of disagreeable winds, dust, and sudden weather changes, encourage outdoor life, is to be recommended. The climate does not cure; it is an important help in the treatment of the disease. Some patients, especially elderly people and those suffering from nervous, cardiac, or bronchial affections, fare better at lower altitudes; but higher altitudes, with the stimulating effects, deep respiration, and active use of the lungs which they induce, often offer many climatic conditions favourable to outdoor life and hence of great benefit in the treatment of the disease. The dry, pure air and abundant sunshine of many of the well-known mountain health resorts are very favourable climatic helps. Moreover, the smaller temperature ranges of mountain and marine climates are also helpful. In many, if not in most cases, any change of climate is beneficial, but especially so if such a change is accompanied by the favourable conditions just enumerated. Ocean air, although damp, is beneficial to many patients because of its purity, its salinity, and its small temperature ranges. Hence an ocean voyage, with its relief from unsanitary or harmful occupations, may be an excellent restorative. Results obtained in the treatment of tuberculosis by climatic change vary through a wide range. The reasons for such discrepancy are

to be sought in the difference in the stage of the disease treated, and in the habits, food, and mode of life of the patients.

Pneumonia. Pneumonia is found almost everywhere, in the tropics probably quite as commonly as in colder latitudes, and at high altitudes as well as at sea-level. A greater frequency of pneumonia generally follows cold, damp weather, with marked changes of temperature, which lower the vitality and are conducive to chills. Hence the disease is most prevalent in the colder months. Among the predisposing causes, physical weakness following other diseases is potent, as are mal-nutrition and similar debilitating agencies. Severe cold spells are likely to be followed by an increase of pneumonia, especially among elderly persons and children. Negroes who have gone to cold climates are very subject to the disease.

Diphtheria. Although geographically widely distributed, diphtheria is chiefly a temperate zone disease, occurring sporadically or epidemically, however, in tropics and polar latitudes. Like other infectious diseases of the temperate zone, diphtheria is most frequent in the colder months, because the conditions of life are then most favourable to contagion, and because vitality is then most lowered by the prevailing weather conditions. Diphtheria is more common at low altitudes than high.

Influenza. The well-known disease, "gripe," caused by a specific organism discovered in 1892, is

occasionally very serious, and is apt to be closely followed by epidemics of pneumonia and other diseases of the respiratory organs. Although very carefully studied, there is no certain evidence of any influence of weather, climate, or soil upon the disease. The last great epidemic of influenza, in 1890 and thereabout, is believed by Assmann to have been associated with dry spells and with the carriage of dust. The worst outbreaks have been in the colder season, when indoor life, less fresh air, and overcrowding would naturally help to spread the contagion. The fact that those who are suffering from influenza are often not kept indoors explains a general spread of the disease.

Bronchitis. Bronchitis is most common in the higher latitudes, and in the cold months, when the temperature is low and when sudden and rapid variations of temperature are frequent. Dust, blown from the dry surface of streets and the like, helps to irritate the throat and nasal passages. Relief from bronchitis may be found where the climate is warm and uniform; the air soft and balmy; where there are no irritating winds driving the dust to and fro, and where sunshine is abundant.

Rheumatism. Rheumatic affections are, as a whole, more common in colder than warmer, and in damper than drier climates, but may be classed under the temperate zone. Exposure to cold and wet, bringing on chills, and sudden temperature changes, especially in damp climates, while not the cause of

rheumatism lowers the vitality in such a way that the specific cause may assert itself. In many cases a change of altitude makes no difference whatever; it may, in fact, aggravate the trouble.

Measles and Scarlet Fever. Both measles and scarlet fever are independent of weather and climate, except in so far as the colder, more inclement, months involve an unhealthier mode of life, with less attention to sanitary measures. A maximum is usually found in the colder months, when infection is most likely. Measles occurs in all climates, but usually most commonly and most severely in temperate latitudes. Scarlet fever is essentially a disease of the temperate zone. Isolation from sources of infection is more important than any climatic control in these diseases, which show very various relations to season, altitude, and race.

Typhoid Fever. Typhoid fever is found in almost all parts of the world. Although common in the tropics, being one of the most generally fatal diseases there, especially among recent European arrivals, it is not, according to Manson, properly classified as a tropical disease. It is very prevalent in the temperate zone, having a maximum frequency in late summer and autumn, and is certainly largely preventable by good sanitation and pure food and water. The germs of typhoid fever are killed in a few hours under direct sunshine, and their growth is slow even in diffused daylight. The well-known studies of Pettenkofer, at Munich, showed an inverse

relation between the ground-water level and the prevalence of typhoid, but this appears not to be a universal relation. The view formerly held regarding a connection between temperature and humidity and typhoid epidemics has now generally been abandoned.

Whooping Cough. Whooping cough is more prevalent in temperate and cooler climates, where the temperature changes are marked and where the respiratory organs are most affected, and is rare and less severe in warmer latitudes. But the absence of whooping cough is doubtless often to be explained on the ground that it has not been imported, rather than on any direct climatic basis. Although commoner and more severe in the cooler months, epidemics may occur at all times, without relation to altitude. Croup, also, prevails chiefly in damp, cool weather, with sudden changes.

Cholera Infantum. Among the summer diseases of the temperate zone, cholera infantum occupies a very prominent place. It increases with rising, is at a maximum with maximum, and decreases with falling, temperatures. The greater and more continuous the heat, the more general is the disease. Cool spells check it immediately. It is more common in the overcrowded and overheated quarters of the city than in the country, and may be greatly checked by the use of pure milk and fresh food.

Hay Fever. The specific cause of hay fever has been much debated, but is generally regarded as

vegetable pollen of some sort. The particular kind of pollen may differ in different cases. The irritation is naturally confined to the season of plant growth. Relief may generally be secured by seeking a higher altitude, where the cause of irritation is absent, and where the air is pure and clean. Sea voyages, also, are beneficial.

Polar Zones: General. The north polar summer, as has been pointed out, in spite of its drawbacks, is in some respects a pleasant and healthful season. But the polar night is monotonous, depressing, repelling. Parry said that it would be difficult to conceive of two things which are more alike than two polar winters. An everlastingly uniform snow covering, rigidity, lifelessness, silence—except for the howl of the gale or the cracking of the ice. Small wonder that man feels like an intruder. Small wonder that the polar night has sometimes unbalanced men's minds. Extraordinarily low winter temperatures are easily borne if the air be dry and still. Nansen notes " not very cold " at a temperature of — 22°, when the air was still. Another Arctic explorer, at — 9°, says " it is too warm to skate." Zero weather seems pleasantly refreshing if clear and calm. But high relative humidity and wind—even a light breeze —give the same degree of cold a penetrating feeling of chill which may be unbearable. Thus the damper air of spring and summer usually seems much colder than the drier air of winter, although the temperatures may be the same. Large temperature ranges are

endured without danger in the polar winter when the air is dry. When exposed to direct insolation, the skin burns and blisters; the lips swell and crack. In severe cold the vitality of the body is lowered, the pulse slackened, and the ability to bear hardships decreased. The surface of the body cools first; the blood circulates more slowly; the surface blood-vessels contract, and the blood then becomes internally congested; the lungs and heart may be affected, and in extreme cases death results. The danger of freezing is naturally greatest in the case of the hands, feet, ears, and nose, which are most exposed and can least well be kept warm. The skin may swell, become thick and hard, and break open. The power of resistance to extreme cold depends on the physical condition, clothing, food, exercise, exposure to sunshine, dampness, wind, and other factors. The feeling of cold is increased by hunger, and rheumatic people usually suffer most.

The physiological effects of polar cold and darkness have been fully reported upon by Arctic and Antarctic explorers. The recent expeditions, on which very careful attention has been given to picking the men, as well as to their health, diet, exercise, and general hygiene, have shown much less marked effects than did the earlier expeditions. Among the effects which have often been observed are a weakening of the senses of taste and of smell, as a result of congestion and over-secretion on the mucous membranes; depression, apathy, and sleepiness, often

followed by nervous excitement and even in some cases by insanity; anæmia; tendency to digestive disorders and dyspepsia; constipation or diarrhœa; greatly lessened perspiration; fading of hair and beards; change of colour of the skin to pale and yellow; a lowering of the body temperature. The monotony of the polar night is depressing to a degree. Thirst has been one of the greatest plagues of Arctic explorers in the past. The result of a large evaporation from the lungs into the dry, cold air, thirst is a characteristic of the deserts of snow and ice as it is of the deserts of sand. The relief of this thirst by eating snow is dangerous, for it leads to inflammation of the throat and to digestive and bowel troubles. Moreover, such relief is but temporary.

It has been pointed out by Dr. F. A. Cook that, like the polar animals, the Eskimos can withstand long periods without food; that their intestinal capacity is increased in such a way that they can assimilate a constant meat diet, and that they are protected against the cold by thick, fatty tissues and by their profuse peripheral circulation.

Life is hard in the polar zones. Deaths by drowning in gales at sea, by freezing, and in snowstorms are frequent. Yet, on the other hand, most of the diseases which have been discussed in this chapter are rare or absent in the far north. There is a remarkable infrequency of infectious diseases. Polar air is very free from micro-organisms—a fact which is due chiefly to lack of communication with other parts of

the world; colds are reported as rare or unknown, although changes of temperature are often frequent and large. The summer sun, both by direct and by reflected radiation, burns and bronzes the skin, and may cause snow-blindness. An Arctic summer, with its long days, crisp, clean air, and sunshine, offers conditions which are doubtless excellent for many nervous and gastric troubles, and one may predict a considerable development of summer resorts within the Arctic circle for the pleasure-loving, wealthy, and unoccupied persons of the north temperate zone.

Scurvy. Scurvy has been considered a polar disease *par excellence,* because it has, in the past, been prevalent on Arctic expeditions, and is found to-day in northern latitudes. Scurvy is, however, known also in many other parts of the world. It is found under conditions of overcrowding, and of poor ventilation, which are natural consequences of extreme cold. Cold is not the cause of the disease, for scurvy is found in warm countries also; but rigorous climatic conditions, poor food—especially the lack of fresh vegetables, over-exertion, depression, lowered vitality by exposure to cold, etc., are predisposing causes. The best preventives of scurvy are good food, an active outdoor life, and mental stimulation. With these precautions and good hygiene, scurvy has almost disappeared among civilised nations.

Climate and Health: General Conclusions. The old view concerning the paramount influence of climate upon health is being replaced by the view that

good hygiene is of more importance than climate alone. Medical science has done much to stamp out some diseases like small-pox, and it will in time probably largely stamp out others, like malaria, or yellow fever, or even tuberculosis and diphtheria. Man himself, not climate, is being held responsible for the occurrence of this or that disease or epidemic, for its distribution, and for the death-rates resulting from it. Man has lowered the death-rate from disease most wonderfully. He can lower it still further. Vaccination for small-pox; preventive inoculation for plague; antitoxin for diphtheria; good food, pure air, and exercise for scurvy; draining swamps and pools and the use of mosquito netting for malaria; pure water for cholera, typhoid fever, and dysentery—these are but a few of the methods now employed by man in his war against disease.

The influence of climate is by no means to be discarded as of no account, for that it acts, in many ways, both directly and indirectly, has been shown in this chapter. The newer view regarding the influence of a change of climate as a preventive, or restorative, is that a change of residence, habits, occupations, food, is usually of more importance than the change in atmospheric conditions. If pure air, good food, freedom from worry, time for rest, proper exercise, outdoor life, and a congenial occupation are provided, many bodily and mental ailments will yield to the treatment. Climate is to be considered, because it affects our bodily comfort; it may be dull, rainy, and

cheerless, or bright, sunny, and exhilarating; it may tend to keep us indoors, or it may tempt us to go out. Thus some climates will naturally be avoided, and others sought out, and the choice of a suitable climate will depend upon the disease to be dealt with. As a recent writer has well said, climate may "play an important part in the curative process, but the climate of certain localities does not possess any peculiar properties which act as a specific on certain diseases."

CHAPTER VIII

THE LIFE OF MAN IN THE TROPICS

Climate and Man: General—Some Old Views Regarding the Effects of Climate on Man—Factors in the Problem Other than Climate—Climate and Habitability—The Development of the Tropics—The Labour Problem in the Tropics—The Government of Tropical Possessions—Primitive Civilisation and the Tropics—Dwellings in the Tropics—Clothing in the Tropics—Food in the Tropics—Agriculture, Arts, and Industries in the Tropics—Some Physiological Effects of Tropical Climates—The Equatorial Forests—The Open Grass-Lands of the Tropics: Savannas—Trade Wind Belts on Land: the Deserts—Trade Wind Belts at Sea—Monsoon Districts—Tropical Mountains.

Climate and Man: General. Man's climatic environment affects him in many ways. His clothing, dwellings, food, occupations, and customs; his physical and mental characteristics; his systems of government; his migrations; his history—all are affected to a greater or less degree.

Civilised man protects himself more or less successfully against unfavourable climatic features. Thus, there is a gradual transition from the primitive shelter made of branches of trees, of skins, or leaves, to the permanent and highly elaborate modern building, which is both heated and cooled artificially. The building materials; the methods of uniting these ma-

terials, as by braiding, or binding, or by the use of mortar, usually show the control of climate. Moreover, the material often determines the general plan of the building. There is also the transition from the primitive and scanty clothing made of leaves or bark where trees grow, or the skin of an animal where trees are lacking, or warmer clothing is needed, to the manufactured and perhaps imported garment of wool, or cotton, or silk. Again, there is the increasing variety of food, from that of primitive man, supplied directly where he lives, to the highly varied diet found in a civilised community to-day, to which distant latitudes are made to contribute their local delicacies.

All these changes man has brought about. But he cannot change his climate. Slight local modifications may be secured here and there, as by planting trees to serve as wind-breaks, or perhaps by increasing the relative humidity a little through the construction of an artificial reservoir. No such modification is possible in man's climatic environment as has been accomplished on the surface of the land under human agency. The atmosphere is as essentially unalterable as it is all-pervading. When we see how plants and animals are affected by atmospheric conditions, it is not unreasonable that we should expect man to show effects of a similar kind.

Some Old Views Regarding the Effects of Climate on Man. It is, however, easy to go too far in calling upon climate to explain phenomena which we may

otherwise find it difficult to account for. This was the mistake formerly made by many writers on this subject, as has been clearly pointed out by Ratzel in his *Anthropogeographie,* where he gives an outline of many of these earlier views. Maupertius and others held that the colour of man's skin becomes paler with increasing distance from the equator. Livingstone wrote that in Africa religious ideas also seemed to depend on distance from the equator. One writer held that cold produces a small stature; another believed that the Pygmies are small because of the heavy seasonal rains which fall in hot equatorial Africa. Climate was believed to explain the overhanging eyebrows and partly-closed eyes of the negro; the small eyes and beardless faces of the Chinese; the (supposed) fact that more twins were born in Egypt than elsewhere. And so on. The broad generalisations of Montesquieu, Voltaire, Buffon, Hume, Buckle, and others, furnish interesting reading, and contain much that is suggestive and instructive, but they usually carry us well beyond the range of reasonable probability. Even Hippocrates's observations on climatic controls are not without value to-day.

Factors in the Problem Other than Climate. To most of these older writers climate meant more than it does to-day. It included much of what is now termed our whole physical environment. Moreover they based their conclusions upon incomplete records, covering far too short periods of time. It must be

remembered that we are dealing here with large, important, highly complex phenomena. Man moves readily from place to place, from climate to climate. His food, drink, habits, occupations; to some extent his physical and mental characteristics, change in consequence. Inheritance, intermarriage, environment, opportunities, soil, and many other factors enter in to determine what changes individual man and the race as a whole shall undergo. Time is a very important element in the final result, for in time a gradual adaptation to new conditions takes place. Climate is but one of many controls, albeit a most important one, for it largely determines what many of the other factors, such as diet, customs, and occupations, for example, shall be. The task of giving climate its proper place as a factor controlling the life of man as a whole is a difficult one, which cannot be definitely and satisfactorily solved to-day, or to-morrow.

It would take us far beyond the limits set for our present volume were we to attempt any consideration of the many complex problems in connection with the possible influences of climate upon the physical and mental characteristics of man. Investigations along these lines have given rise to much debate. It is our present purpose merely to point out some of the more simple and obvious ways in which the life of man is controlled by climate. This control, it should be observed, is either direct, where physical and mental changes under climatic stimulus are concerned, or

indirect, as when climate acts upon man through its influence over the distribution of the animals and plants upon which man depends for his food, clothing, and materials of various kinds.

Climate and Habitability. Climate determines both how and where man shall live. It classifies the earth's surface for us into the so-called habitable and uninhabitable regions. The deserts of sand and the deserts of snow and ice, whether the latter be near sea-level or high up on mountain tops, are alike climatic, the former because of aridity; the latter because of cold. The only non-climatic deserts are recent lava-flows. Where a soil is present which is not frozen for much over half the year, and where there is reasonable temperature and sufficient rainfall, plants and animals are found, ranging from few and lowly forms where conditions are the hardest and where all organic life is especially adapted to these conditions, to the greatest abundance where conditions are most favourable.

Man is influenced by much the same controls as those which affect plants and the lower animals. From the highest latitudes he is excluded by cold. The higher altitudes are hostile both because of cold and of diminished pressure. The deserts of sand are uninhabited, or thinly populated, by reason of aridity. Forests, where rainfall is abundant, are unfavourable to a dense population. The trees must be cleared away before settlement is easy. Man is widely distributed over the earth's surface. In his migrations

he has carried with him, beyond their original limits, many plants and animals. Ratzel points out that the coldest place in the world in January is a large Siberian city, Verkhoyansk, while one of the hottest places in the world is Massowa, on the Red Sea, the capital of the Italian colony of Eritrea. But the life of man is harder here and easier there, according to climatic conditions and the scarcity or abundance of plant and animal life.

Man is distributed in great belts around the world, corresponding roughly to the broad zones of vegetation, desert, steppe, and forest, the limits of which are set by temperature and rainfall, but man is much more dependent on rainfall than upon temperature. Water he must have, directly from the clouds, or indirectly through rivers, or springs, or wells, or from melted snow and ice. There are certain common conditions of life which affect the people who live in the same zone in the same broad, general way, just as these zones have similar general conditions of winds and of rainfall. This, as Ratzel has pointed out, means that there is a climatic factor at work to maintain differences between the people of different zones, in spite of the great movements which are constantly tending to produce uniformity. Obviously, the differences in the life of man which depend upon climate will be most noticeable, and will be likely to have the greatest historical significance, when marked differences of climate are found close together, as in the case of mountain ranges like the Alps, or of a pro-

nounced lowland, plateau, and mountain topography like that of Peru or Mexico.

All the regions of sparse population are gradually being encroached upon by an invasion from their borders. Forests are being cleared and replaced by open agricultural lands. Wheat and corn are replacing grass on the steppes and savannas, especially where irrigation can be practised. Deserts are being reclaimed for farming here and there where water is available. The more civilised man becomes, the denser the population which the different parts of the earth can be made to support. From the wandering hunting and fishing tribes of the African forest or of the borders of the Arctic sea, through the farming populations of the cleared forest and of the steppe, to the crowded industrial centres of the modern city, there is such a gradation. It is the story of a more complete to a less complete mastery of man by his environment. But in spite of all that man can do, the larger climatic limitations persist. The Greenland desert of snow and ice, and the Saharan desert of sand, must remain practically deserted.

The Development of the Tropics. Within the tropics, under the equatorial sun, and where there is abundance of moisture, animal and plant life, reach their fullest development. Here are the lands which are most valuable to the white man because of the wealth of their tropical products. Here are the tropical "spheres of influence" or "colonies" which are among his most coveted possessions. It is in this

belt that food is provided for man throughout the year without labour on his part; in which frost and drought need not be feared; where shelter and clothing are so easily provided, and often so unnecessary, that life becomes too easy. Nature does too much; there is little left for man to do. The simplicity of life, so far as providing food is concerned, has been emphasised by many writers. We are told that three bread-fruit trees furnish enough food for one man; that a labourer needs only twelve bananas for his daily food; that one day a week is enough time to spend in caring for a manioc plantation; that two days' work a week is often enough to enable a man to support a family; that a month's labour will provide for a Malay more sago than he can use in a year, etc. Stories are told of shipwrecked seamen in the tropical Pacific who lived for many days on one cocoanut a day for each man. Captain Cook put the case very emphatically when he said that a South Sea Islander who plants ten bread-fruit trees does as much towards providing food for his family as does a man in northern Europe who works throughout the year.

In a debilitating and enervating climate, without the necessity of work, the will to develop both the man who inhabits the tropics, and also the resources of the tropics, is generally lacking. Voluntary progress toward a higher civilisation is not reasonably to be expected. The tropics must be developed under other auspices than their own. "Where nature lavishes food and winks at the neglect of clothing and

shelter, there ignorance, superstition, physical prowess, and sexual passion have an equal chance with intelligence, foresight, thought, and self-control." [1]

There is no superfluous energy for the higher things of life. Thus it has come about that the natives of the tropics have the general reputation of being indolent and untrustworthy; of always being ready to put off until "to-morrow." Obviously, no such sweeping generalisation is to be taken too literally, for the lower latitudes have produced many men far from deficient in physical and intellectual power. Moreover in those parts of the tropics where natural conditions are more severe, the natives are usually more industrious. But it is true that the energetic and enterprising races of the world have not developed under the easy conditions of life in the tropics. As Edward Whymper's Swiss guide said of the natives of Ecuador, "it would be good for tropical peoples to have a winter." Guyot has put the case in this way:

> A nature too rich, too prodigal of her gifts, does not compel man to snatch from her his daily bread by his daily toil. A regular climate, the absence of a dormant season, render forethought of little use to him. Nothing invites him to that struggle of intelligence against nature which raises the forces of man to so high a pitch, but which would seem here to be hopeless. Thus he never dreams of resisting this all-powerful physical nature; he is conquered by her; he submits to the yoke, and becomes again the animal man,—forgetful of his high moral destination.

The movements of the body, the habit of carrying

[1] John R. Commons, *The Chautauquan*, May, 1904, p. 222.

loads on the head, even the native dances, have been thought by some to show the enervating effects of the climate. One writer has even gone so far as to see similar effects in the domestic animals, which he believes to be more docile than those in extra-tropical latitudes.

The Labour Problem in the Tropics. "What possible means are there of inducing the inhabitants of the tropics to undertake steady and continuous work, if local conditions are such that from the mere bounty of nature all the ambitions of the people can be gratified without any considerable amount of labour?" In these words, Alleyne Ireland well sums up the labour problem in the tropics. If the natives are, on the whole, disinclined to work of their own accord, then either forced native labour, which is contrary to the spirit of the times, or imported indentured labour, becomes inevitable if the tropics are to be developed. With few exceptions, and those where the pressure of a large population necessitates labour, effective development has been accomplished only where imported Chinese, Japanese, or coolie labour has been employed, under some form of contract. Negro slavery began in the West Indies, under early Spanish rule, and its perpetuation was certainly in part aided by climatic controls. The best development of many tropical lands depends to-day upon Chinese labour. It will be so in the Philippines. In Java, Holland has succeeded by forcing the natives to work.

With a large native class which is indolent, working intermittently for low wages, or which is bound under some form of contract, it follows that the native or imported labouring classes are separated by a broad gulf from the upper, employing class, which is usually essentially foreign and white. The latter class tends to become despotic; the former, to become servile. Marked social inequalities thus result, accentuated by the fact that the foreign-born white is usually debarred from all hard labour in a hot tropical climate. White labourers are not likely to become dominant in the tropics for two reasons:—first, because the climate is against them; and second, because the native is already there, and his labour is cheaper. White men are not doing the hard daily labour of India, or of Java, or of the Philippines, or even of Hawaii. They are directing it.

The Government of Tropical Possessions. The government of European possessions in the tropics has thus far been determined chiefly by three considerations: (1) The general incapacity of the natives, through ignorance, or lack of interest, or their undeveloped condition, to govern themselves properly. (2) The fact that the white residents are generally comparatively few in number and are only temporarily in the country, to make money and then to go home again. The white population is often composed chiefly of men—soldiers, officials, merchants, adventurers. There is little inducement to found permanent homes. (3) The marked class

distinctions already referred to. These generalisations must obviously not be carried too far. Hawaii, very favourably situated as regards climate, will in time become an American State, and Brazil, most of whose immense area is typically tropical, has an increasing European immigration of permanent settlers. But what has been said is, in the main, true. The white residents constitute a caste, and naturally become the rulers, the home government retaining general control, often by force of arms. The native population, although largely in the majority, may have little or no voice in its own government. This is clearly not a democracy. It thus comes about that the tropics are governed largely from the temperate zone; the standards, ideals, motives, come from another land. And where governed under their own auspices, as independent republics, the success has not been great. Buckle first strongly emphasised the point that hot countries are conducive to despotism and cold countries to freedom and independence; and James Bryce has recently clearly set forth the climatic control of government in an essay on "British Experience in the Government of Colonies" (*Century,* March, 1899, 718–729). The very Europeans who exercise the controlling power in the tropics, themselves tend to become enervated if they live there long; they lose many of the standards and ideals with which they started; they not uncommonly tend to fall towards the level of the natives rather than to raise the standards of the latter. The pecu-

liar situation which may arise from the government of a tropical possession in which the white race does not become acclimated has been emphasised by Dr. Goldwin Smith in a recent discussion of British rule in India. "British Empire in India," he says, "is in no danger of being brought to an end by a Russian invasion. It does not seem to be in much danger of being brought to an end by internal rebellion. Yet it must end. Such is the decree of nature. In that climate British children cannot be reared. No race can forever hold and rule a land in which it cannot rear its children." The future of tropical possessions and "spheres of influence" offers many problems of great complexity, the solution of which is largely controlled by the factor of climate.

Primitive Civilisation and the Tropics. There are reasons for thinking that primitive, pre-historic man, in his earliest stages, when most helpless, was an inhabitant of the tropics; that he lived under the mild, uniform, genial climate of that zone, where food was easily obtained and protection against the inclemencies of the weather least necessary. There has been a belief that southern Asia, bordering on the Indian Ocean, with its numerous bays, was probably the cradle of humanity. Civilised man is believed by many to have appeared first on the delta formed at the head of the Persian Gulf by the Tigris and Euphrates rivers, where also wheat was very likely first grown. Ancient civilisations seem to have developed in the drier portions of the tropics, where irrigation

was necessary in order to insure abundant and regular crops, and where lived races more energetic and more hardy than those of the damper and rainier portions of the tropics, with more luxuriant vegetation. As Professor Hilgard [1] has well said:

> It is hardly doubtful that the ancient 'Kulturvölker' recognised these advantages (of irrigated lands) by experience, and eschewed the laborious task of rendering cultivable the comparatively infertile, or, at least, readily exhausted, lands of the forest regions. . . . And it is also clear that, inasmuch as the establishment and maintenance of irrigation canals necessarily involve coöperation, and therefore a rather high degree of social organisation, the conditions of the arid regions were exceptionally conducive to the establishment of the highly complex polities of which the vestiges are now being unearthed in what we are in the habit of calling deserts.

Civilisation was thus probably first developed, not where the overwhelming superabundance of nature's gifts seems to offer the best conditions, but where man was under some stress of labour, some spur to effort, in less favourable natural conditions, but such as developed him. Within the tropics, the greatest progress later came, not on the damp lowlands, but on the less fertile plateaus of Mexico and of Peru, where the Aztecs and Incas made their marvellous progress in the drier, cooler, and more rigorous climates of altitudes over 7000 or 8000 feet above sea-level. Ratzel has pointed out,

[1] E. W. Hilgard: "The Causes of the Development of Ancient Civilisations in Arid Countries," *No. Amer. Rev.*, vol. 175, 1902, p. 314.

in the case of the ruins found on the lowlands of Yucatan and of farther India, that when such building operations are carried through by the autocratic rule over a subject class, the situation is very different from that in which we see spontaneous action on the part of a whole people.

The nations living in ease on the tropical lowlands were naturally, from early days, the object of frequent attacks and invasions at the hands of the more active and more warlike races living in more rigorous climates farther north, or at greater altitudes on mountains or plateaus. The invading tribes, having in time become enervated by an easy existence on the warm lowlands, have themselves often been later overcome by a new enemy from the north. Some of the greatest migratory movements in history have taken place from colder to warmer climates, as part of this general equatorward tendency in both temperate and tropical zones. The barbarous tribes broke through the northern passes and descended onto the more genial and more fruitful lowlands of India, being helped to do this by the ease of the descent. Such mountain systems as the Himalayas, or the Alps, stretching east and west, are natural climatic divides between more genial and more severe climates, and have often been crossed by invading armies from the north. The descent of the Aryans into India; the Manchurian conquest of China; the invasions of Greece and Italy from the north; the southward movement of Toltecs and Aztecs in Mex-

ico, have been cited as illustrations of this equatorward tendency. In the southern hemisphere, it has been suggested that the Kaffirs have shown the same tendency—there northward,—as did the native Patagonians in their predatory expeditions to the north. The equatorward tendency may be seen to-day in the extension of European "spheres of influence," especially in Africa, the object now being essentially a mercenary one, and not a seeking for new homes in a more genial climate.

Dwellings in the Tropics. Dwellings, clothing, and food are easily provided in the hot climates of the moist tropics. In the deserts and on the mountains the conditions of life are harder. The protection that is needed against sun and rain, and the lowered temperatures of the tropical night, is usually very simple. Man spends most of his life outdoors. The building materials are ready at hand and simple. Many of the primitive native huts are loosely made of bamboo or other pliable trees, where such are available (*e. g.*, the mimosa used by the Hottentots); of palm and cocoanut leaves, sugar-cane, or grass. Pointed roofs, supported on poles, and wooden frames with mats for walls, are a characteristic style of architecture. In some places temporary huts are made of skins, while more permanent dwellings are better built, with good roofs. The permanent dwellings in tropical cities are oftenest built of stone, with thick walls. The old Spanish and Portuguese idea was also to have narrow streets, in order that the sun-

light might be shut out as much as possible. In the newer portions of tropical cities, however, wide streets and fine boulevards are being laid out. In the modern houses built for European residents in the tropics, the rooms are large, airy, and well ventilated; there is a minimum of furnishings; there are broad verandas with screens for protection against the sun; there is a proper air space between roof and ceiling. Stoves and fireplaces for heating purposes are unnecessary, and the absence of chimneys on the tops of city houses has often attracted the attention of newcomers from colder latitudes. Nevertheless, in some places the natives are so sensitive to the nocturnal cooling that they keep themselves warm by fires at night. Much difficulty is experienced on account of the destructive action of ants and other insects, and of the dampness, as well as of sudden tropical rains and floods. Even in dry climates, buildings do not last well, unless built of stone. As the prevailing winds are easterly, the eastern quarters of the cities are usually the more desirable and the more fashionable, and are therefore inhabited by the wealthier classes. It is the habit of those who live in the tropics to stop work and stay indoors during the hottest part of the day. Business is done in morning, or later afternoon, and the afternoon *siesta* has become a characteristic of the people. The late afternoon is the time for the fashionable outdoor life in the park, on the promenade, or at the club.

Clothing in the Tropics. The clothing of the natives of the tropics is of the simplest kind, often so scanty as hardly to be called clothing at all. In the moister portions it not infrequently consists solely of aprons made of grass, leaves, bark, or reeds. The children generally go naked. Where the diurnal temperature changes are marked, heavier clothing is usually worn at night. The clothing of Europeans and Americans is loose and light in colour and weight, but thin woollens are by no means to be discarded altogether, for they are useful during the cooler evening hours. Light headgear, for protection against the sun, such as wide-brimmed straw hats or pith helmets, sun umbrellas, and low shoes are used. Great care has been taken to devise the most suitable uniform for white troops in the tropics, even down to the most minute details of equipment. The kind of material, the number and cut of the different garments, even the best kind of belt and shoulder-straps, have received attention. Campaigning in the tropics is very different from ordinary service in the temperate zones, and all these details need care. It is the general opinion that a loose, light uniform, of porous material, with a minimum of straps, belts, and pouches, is the best. As to materials, khaki has come into extensive use and is very popular. "Keep the head cool and the abdomen warm" is the best rule for white residents of the tropics to follow.

Food in the Tropics. Fruits, especially the banana, cocoanut, and bread-fruit, and rice, manioc, yams, sago, and sugar-cane are staple articles of food. Meat and fish are not much used. In the deserts the date-palm is an important article of food, and where irrigation is practised a variety of cereals and fruits is usually grown. Of late years, much attention has been paid by military officials to the question of the best ration for white troops who serve in the tropics. The general feeling is that a light diet consisting chiefly of fruit, vegetables, and cereals, with a minimum of nitrogenous, heat-producing foods, is the most likely to keep the men in good health. A light midday meal is recommended. There are, however, those who hold that the prevailing anæmic condition of the tropical natives is largely due to the deficiency of meat in their diet, and who therefore urge that meat should be eaten in reasonable quantity.

There is much difficulty in preserving perishable food-products. Such articles sent from cooler latitudes for use in, or for transportation across, the tropics, need special protection, by refrigeration or quick carriage. The increase of transportation by steam in place of sail, and the opening of the Suez Canal, have both been factors of importance in meeting this difficulty. It is distinctly an advantage for a country to sell its food products to other countries on its own side of the equator. Frozen meat, carried long distances by sea across the tropics, is not as good as fresh meat, and is also poorer than

meat carried at sufficiently low temperatures to preserve, without actually freezing it. The need for preserving perishable food has led to an increasing demand for ice, and hence to the multiplication of artificial-ice plants. Recently there comes a demand from one tropical country (India) for refrigerator cars for the transportation of milk.

Agriculture, Arts, and Industries in the Tropics. The need of labour in order to procure a good return from the ground is so slight that agriculture has not yet made much progress in the tropics as a whole. Where frost need not be feared, where crops ripen all the year around, and where the soil is rich with decaying vegetable matter, agriculture is naturally slow to improve. Yet there are native peoples who have advanced much farther than might be expected, as is seen, for example, in the cultivation of rice in the Malay archipelago and in farther India; in the state of Polynesian agriculture; in the success at farming attained by many negroes in Africa. Tropical soils are by no means all as fertile as is generally believed. The warm rains throughout the year leach out the soil, carrying off many salts and leaving the land poor; the laterite soils which are common in the tropics are very poor in plant-food ingredients.

There have thus far been comparatively few native industries in the tropics, for the reason, doubtless, that the necessities of life are readily supplied without the need of manufacture. In the future, with

increasing exploitation by the white race, and under the control of it, and with growing demands on the part of the natives themselves, tropical industries are certain to develop. Yet many tropical natives show great ingenuity in the use and adaptation of the simple natural products to which they have access. Thus the shell of the cocoanut is made into bowls and other utensils; the cocoanut fibres are plaited into thatch, baskets, and mats; the cocoanut stems are used in the building of houses and boats. Grass and reeds are plaited, and the bark-cloth of the Pacific islanders and of central Africa is so widely used, and serves its purposes so well, that it has very probably kept the natives who use it from advancing to weaving and spinning. Bamboo and rattan are widely used for domestic utensils of all sorts; for hunting and agricultural implements; in constructing houses, boats, rafts, and vehicles for transportation; in making pipes and musical instruments; and for other purposes; even for food, rope, and string. From the tropics man procures many things in addition to the plant products. For example, the warm tropical oceans yield him pearls and corals. It is an interesting fact that, at the present time, European countries, particularly Germany, are devising and manufacturing machines especially intended for harvesting and preparing for export the products of the tropics, such as machines for splitting cocoanuts; for preparing and extracting oil from the palm fruit; for making caoutchouc from the sap of the rubber

tree, etc. Germany is also devising plans for tropical cultivators, railroads, and houses.

Special precautions are necessary in packing many manufactured goods that are to be transported across the equator, in order to protect them from injury by the dampness. Leather goods, textiles, and paper are liable to be stained. Arms, cutlery, and all metal goods need the utmost care to keep them from rusting. These are best preserved when packed in cases lined with some absorbent wood well saturated with hot paraffine wax. It has recently been pointed out in a Vienna trade journal, that the preservation of lacquered shoes sent from Europe to Australia depends upon the circumstance whether they may be kept moderately cool by the ocean water, low down in the ship's hold, or are near the deck, exposed to the heat. In Indian warehouses woven goods are affected by the dampness in such a way that they have different lengths, although all uniformly woven. Even in the dry month of February, at Bombay, closely woven imported calicoes, exposed to the air, experience changes in length from day to day amounting to 3 per cent. Ordinary salt absorbs so much moisture in the damp latitudes that it has been necessary to prepare a salt which shall escape this difficulty.

Some Physiological Effects of Tropical Climates. We are not here concerned with the many complex questions, physiological and ethnological, which have arisen in connection with the effects of tropical climates upon man. There has been much debate con-

cerning the effect of the climate upon the colour of the skin. It was natural that many early writers should see in the black skin of the negro an effect of the tropical sun, and should explain the paler colours, and white, as resulting from residence in higher latitudes. It was pointed out, *e. g.*, that among certain tropical natives the women, who live indoors, are lighter in colour than the men, who are more exposed. It may be remembered that Darwin, in his *Descent of Man,* pointed out that the distribution of coloured races does not coincide with corresponding differences of climate, and that no change in colour has taken place in the Dutch who have lived for several generations in south Africa. Darwin also thought it not an improbable conjecture that the immunity of negroes from certain diseases might be correlated with the colour of their skins, and that this colour might have been acquired because darker individuals escaped during successive generations from these diseases. However opinions may differ concerning the origin of the black skin of the negro, it is clear that this colour is an advantage, rather than otherwise, in helping to cool the body through profuse perspiration and the resulting evaporation. Black skin, however it may have been developed, seems to be well suited to a hot climate. Major Charles E. Woodruff, of the United States Army, has lately maintained that the failure of the white races to colonise the tropics is due to the excess of light which there prevails, and not to the heat or humidity. He

believes that the white man, especially the blond, gradually becomes disinclined to work on this account, grows neurasthenic, and finally breaks down. An effect of climate upon the kind of hair has also been claimed, but on this point, again, Darwin has noted that although there are reasons for thinking that the growth of hair is affected by cold and dampness, he had "not yet any evidence on this head in the case of man." Schlagintweit called attention to the fact that the inhabitants of Nepal wore much less head-covering than Europeans, and did not suffer. The sallow, anæmic complexions of white inhabitants of the tropics are a subject of general comment.

There are other physiological matters which must also be passed over without discussion. For example, it is alleged that a preponderance of females in warm climates is the effect of the light diet of mothers in the tropics, whereas a meat diet produces more males.[1] Direct proof of the assertion that sterility in the white race ensues after three generations in the tropics is hard to find.

The Equatorial Forests. In the equatorial belt we find the hot, sultry, cloudy conditions of the doldrums, with frequent heavy rains. When the doldrums migrate north and south, and the trade winds take their place, there are clearer skies for a time, and little or no rainfall. There are two rainy seasons near the equator (*equatorial type*), and one

[1] Schenck: *Einfluss auf das Geschlechtsverhaltniss*, 1898.

rainy season farther away (*tropical type*). The life of man in the equatorial belt as a whole is controlled by the rains. The dense tropical forests of equatorial Africa, South America, the Malay peninsula and archipelago, grow where the rainfall is heaviest. These forests are dark and depressing; crowded with creepers and plants of innumerable varieties; rich in valuable woods such as mahogany, ebony, and rosewood; in sap-products such as rubber, and in drugs such as quinine. Pöppig has compared the native South American tribes with their forest trees. Man develops rapidly there, as does the vegetation. He also ages rapidly, like the tree which decays at the time of its best development. The tropical tree does not strike its roots firm and deep into the soil; it spreads them out near the surface, and a high wind overturns it. So it is, according to Pöppig, with the native. Both he and his trees lack the stability and endurance of northern forests and of temperate zone man. There are comparatively few animals in the dense tropical forests. Reptiles, birds, and monkeys are found. The large mammals are in the more open country.

Such a superabundance of vegetation is unfavourable to human occupation. The population is small, and generally at a very low stage of civilisation, as illustrated by the Indians of the Amazonian forests or the Pygmies of the Congo, who wander about without settled homes. The trees and undergrowth act as a very effective barrier to the advance of civilisa-

tion from the margins of the forest. The difficulty and expense of travel and transportation, and of clearing the forest for purposes of agriculture, operate to retard the advance of civilised man. The waves of civilisation, as one writer has put it, beat up against the forest, but only occasionally break through it. The northern forests of Argentina, inhabited by wandering tribes of Indians; the densely wooded Amazonian provinces of Peru; the equatorial forests on the west coast of Africa; the forests of Achin, in northern Sumatra, in the protection they have afforded the natives in their resistance against the Dutch; the eastern forested slopes of Central America, left longest to the native tribes, while the western, more open, and drier slopes were first settled by white men and are best developed—these are all examples of the repelling effects of dense tropical tree-growth where the advance of civilised man is concerned. Even the earlier American civilisations, the Aztec and the Inca, halted before forested areas. It has been pointed out that the Incas were almost as much hemmed in by the forests on the east as by the Pacific on the west.

In the equatorial forests the men hunt and fish; collect rubber or other forest products; do a little planting in the forest clearings, without paying much attention to the crop when planted. By clearing away the forest, these people might extend the area devoted to agriculture, and become farmers. In the clearings at the margins of the forests there is a cer-

tain amount of agriculture, carried on chiefly by the women, who are also occupied with domestic duties while the men are hunting or fighting. Settlements in these clearings are often abandoned. In the Malayan forest the natives are graded from those who are simple nomads to those who have settlements where they cultivate rice in the wet jungles. Rice needs much water, and its cultivation in Java is closely allied with the general question of deforestation. Where the sago palm grows, and provides food without the need of much labour, the natives are least advanced.

Travel through the forest is difficult. Darwin thought it not unlikely that the habit of carrying knives for the purpose of cutting down vegetation contributes much to the frequency of murder among the tropical peoples. Narrow paths, along which travellers move in Indian file, are natural ways of communication unless travel can be by boat, which is obviously quicker and easier. The natives thus naturally live along the rivers. It has been pointed out that there is a connection between the method of carrying goods in the African forests, on the backs or heads of negro porters, and the slave trade, which sells the man as well as the goods. Many of the natives who secure the rubber from the Amazonian forests, or from those of the Congo, are to-day subjected to hardships which equal those of slavery.

The seasonal floods on many rivers, the Amazon for example, oblige the natives to build huts on piles

to keep them above the water. When the waters rise higher than the platforms, the people take to their canoes, until the flood is over. In some places the floods drive the people to the towns, which are built on natural eminences. In New Guinea and in the Mosquito Territory the natives live much in their boats during the rainy season. In fact, in the former country so much time is spent on the water that the people partly lose their ability to walk. They almost become amphibious beings. Sir Charles Eliot reports that some of the native tribes along the Bahr-el-Gebel, at seasons when mosquitoes are abundant, use platforms on poles ten or twelve feet high, as these insects do not fly far above the ground.

The food supply along the Amazon is closely related to the rise and fall of the water. When the river is in flood, the turtles, fish, and aquatic birds migrate to the northern tributaries, or even to the Orinoco, where the dry season is on. With the return of the dry season on the Amazon comes the opportunity of the natives to catch the fish and turtles, and to secure turtles' eggs. There is thus a very general seasonal migration among the people. The flood time is the time of deficient food supply. This explains the origin of the native prayer for a good dry season. The conditions of life on the Mosquito Coast are very similar (lat. 10°–15° N.). The north-east trade there brings the dry season (spring), when the Indians collect the eggs of alli-

gators and turtles on the dry sand-banks. Livingstone pointed out that during the great floods in the inland lake region of Africa the natives live upon, and cultivate, the large ant hills, in the Bangweolo and Moëro districts. On the plateau of western Nyassa, the Ba Bisa profit by the heavy rains in an interesting way. At such times the hollows are swampy, so that elephants driven into them become helpless and are readily killed. Similarly, as reported by Livingstone, the natives of the islands in the Zambezi River utilise the floods and canoes to hunt buffaloes, these animals being easily caught in the water. One writer has pointed out that certain African tribes purposely go naked during the rains, knowing that they are thus less likely to become chilled.

The great value of the tropical forest products is leading, and will still further lead, to the settlement of considerable numbers of whites on the margins of these forests, and along the rivers which flow through them. Thus in Brazil, along the lower Amazon and its tributaries, there are cacao, sugar, coffee, tobacco, manioc, and rice plantations; in some cases also, sugar factories, rice and lumber mills. Large cities and towns thus gradually grow up, like Para and Manaos, and the native tribes come more and more into contact with civilisation.

Travel and transportation are emphatically controlled by climate throughout the equatorial belt. Roads become almost or quite impassable during the rainy season. Lowlands, as in central Africa and in

equatorial South America, turn into swamps or temporary lakes, so that all travel may be stopped. In other places, where boats are used at all seasons, the rains give high water and aid, rather than hinder, travel. The control of the floods of the Chagres River, on the Isthmus of Panama, is one of the most difficult problems with which the engineers have dealt. Work on railroads is always much interfered with during the rainy season, if not interrupted altogether. Dense tropical vegetation seriously obstructs railroad construction and operation. The roadway is constantly being overgrown, and men must be kept at work cutting down the weeds, underbrush, and trees. This involves great expense, and seriously reduces the earnings of the roads. Recently, tank-cars which frequently spray the right of way with a strong poison have come into use, as on the Guayaquil–Quito line in Ecuador, and on the Tehuantepec Railroad. Ties and trestles rot quickly, or are destroyed by insects. Special kinds of ties, such as *lignum vitæ,* or camphor wood, or even iron, have therefore been used. Although vegetation is thus a serious handicap to railroads in the moist tropics, it serves a useful purpose in preventing the sides of steep cuts from sliding down. The absence of frost makes possible cuts with steeper sides than in colder latitudes. Along the older portion of the Panama Canal, which has been built for some years, no masonry was needed to keep the banks from caving in. The heavy vegetation served the purpose of

stone and cement. Fevers and other diseases common in the rainy season of the tropics are also a serious handicap, and floods and landslides add to the difficulties. The sultry heat is another obstacle. Curious complications in the employment of several different kinds of labour arose on the Uganda Railway. For four castes among the Indian workmen, four separate water-tanks had to be provided, and if the water in one tank gave out, that particular one had to be sent by train to be filled, although the remaining three tanks were full. Dr. H. R. Mill has pointed out that there are many features on the Uganda Railway which show climatic control. The cars are built of metal, in order to defy wood-boring insects. They have deep ventilators, protected by wire gauze against mosquitoes. The windows are of green glass to give protection against the glare of the sun.

During the dry season the difficulties are similar to those noted later under deserts. At that time dust makes travelling disagreeable, and instead of streams being impassable, they often dry up, and their beds serve as roads.

A curious relation of thunder-storms and navigation is reported by Hann from Maracaibo, Venezuela. The lightning flashes from rainy-season thunder-storms at the south-western end of the lake of Maracaibo are used by captains in navigating their vessels through the strait of Maracaibo. "El Faro de Maracaibo," as these lightnings are locally called,

gives a good compass-direction for steering a ship on dark nights.

The Open Grass Lands of the Tropics: Savannas. Between the forests on one side and the deserts on the other comes a transition zone of moderate rainfall. Here the forests are replaced by an intermediate belt of more or less open, grassy country, known as the savanna. There are usually a long dry and a shorter wet season (summer). Vegetation has but a short season for growth. Savannas are found in Africa and in South America both north and south of the equator. In Africa they include the Sudan; in South America, the llanos of Venezuela and the campos of Brazil; in Australia, the downs. The open country and the grass cover, which forms natural hay in the dry season, fit the savannas for grazing purposes. The people are essentially pastoral. Population is denser than in the tropical forest, and the people are more energetic and more advanced. The African savannas are abundantly supplied with large animals such as lions, tigers, antelopes, elephants, rhinoceroses, and giraffes.

Their dependence upon grass and water for their cattle forces the inhabitants of the savannas to be more or less nomadic, the more so the more pastoral the people are. They move their tents and household goods easily over great distances, stopping where there are pasturage and water. Their food is supplied chiefly from their flocks and herds, of cows, goats, or camels. Agriculture of a somewhat primitive kind

is often combined with grazing in the better-watered portions of the savannas, the seed being sown at the beginning of the rains. The population there becomes more sedentary. Thus in the Sudan there is a belt of agriculture nearer the equator, where the rainfall is heavier, and a pastoral zone farther from the equator, where there is less rainfall. In these districts the rainfall varies much from year to year, and there are frequent droughts and famines. Thousands of persons may then die of starvation, as has happened in parts of the Sudan, in Nubia, and elsewhere within a few years. At such times the cattle die in large numbers, and where the herds have been lost by famine or disease it has happened that certain native tribes (*e. g.*, the Galla, in eastern Africa), after suffering terribly from hunger, have changed their place of residence, turning in part to plunder and hunting, and in part to farming. A curious case of seasonal migration into the desert has been reported of the Tuaregs, who inhabit part of the region about Lake Chad. The upper class of these people is nomadic, and during the rainy season retires into the desert with its camels, which do not like the rains.

All the savannas will in time be more thickly populated and more valuable than now, owing to the availability of considerable portions of them for agriculture, especially where irrigation can be practised. Under the supervision of white overseers, the natives will become better agriculturists and cattle-raisers.

In South America, as well as in Australia, the savannas are in part being sown to wheat. From the savannas and the neighbouring deserts, ivory, ostrich feathers, palm oil, dates, gums, and so on, are secured.

Trade Wind Belts on Land: the Deserts. The major part of the earth's surface in the trade wind belts is a desert, which forms a marked feature of every rainfall map of the world. These trade wind deserts, because of their great extent, are of immense importance from a human standpoint. They are belts of scanty population. They form great barriers, across which even to-day travel and transportation are difficult and expensive. The interior of Africa has been out of contact with the civilised world largely because of the deserts to the north and south of it. Goods and passengers go around, rather than across them. Trails across the desert are easily effaced by blowing sand, or are shifted as some oasis dries up. Along their margins, where there is a moderate rainfall, or where oases, wells, or streams make permanent settlement possible, the population is more or less sedentary, agricultural, pastoral, and commercial, but even here droughts and famines may occur, and agriculture is not absolutely sure. Rivers which cross the desert gain their water from the rainier lands beyond, and then flow long distances without tributaries. The Nile is the classic example of this. Along such rivers population naturally gathers; irrigation and agriculture are practised, and

the entire valley becomes an oasis. The Nile and the rivers of the coastal desert of South America are illustrations; in the Deccan, also, the river systems are the centres of the densest population. It is difficult to overestimate the effect which the Nile had upon the civilisation of ancient Egypt. It has been asserted with good reason that the annual overflow, by depositing silt and by wiping out the boundaries of individual tracts of land, obliged the ancient Egyptians to develop mathematical skill in re-surveying these lands, as it also led to canal and dam building. Where deserts are irrigated, it is sometimes necessary to guard the water supply, as in Chile and Peru.

In the desert proper, a nomadic life and a scattered population are characteristic and inevitable results of the aridity. As Schirmer has expressed it, "the purer the desert, the more the inhabitants disperse themselves." The Saharan nomads camp for a few months in winter, it may be near the towns, and then travel with their flocks in summer. The Bedouins, although they wander to and fro over a wide area, nevertheless keep within certain recognised limits. In the desert, population gathers in the oases, as on islands. Here the trails followed by the caravans come together, like sailing routes at sea. Thus there is naturally developed a settlement, in which the people are in places so crowded that they may be on the verge of starvation all the time. There are small Arabian towns where the houses are

almost crowded on top of one another, producing something not unlike the modern "sky-scraper" of an American city, where land is scarce and expensive. When such oases dry up, or are encroached upon by the desert sands, they are abandoned, and the ruins, later discovered by some explorer, give the impression of a diminishing population.

The climate of the trade wind deserts is drier and more stimulating, and has larger temperature ranges, than that of the forests and of the savannas. The need of protection against heat and cold is greater; food more difficult to obtain; life a harder struggle. Therefore the desert produces more active, more energetic, and more progressive men. They are independent, bold, and strong. Nachtigal has pointed out the difference between the healthy and vigorous tribes of the Sahara and the less active Sudanese. The hardy, warlike inhabitants of the desert of Persia and Baluchistan have frequently held in subjection the people of the richer lowlands on the west. There is a well recognised difference between the true nomad desert-dweller and the weaker sedentary. From the latter, the former often takes tribute, and if the exactions become unbearable, the unfortunate sedentary farmer may be forced in self-defence to become a nomad himself. The nomadic life of the desert-dwellers tends to make robbers of them, so that pillaging of caravans is not an uncommon occurrence. The utter hopelessness of the isolated Australian desert seems to have led to a most degraded condition

among its inhabitants. Nearly naked, living on the lowest forms of desert life, and practising cannibalism and the murder of the weak and helpless, they have ranked among the lowest human beings in the world.

The trade wind deserts are gaps in the map of the world's civilisation. When the tribes or individuals who live along the margins of the deserts are forced into the deserts, they tend to scatter and disappear. There are also migrations out from the desert into the more fertile regions adjoining, as in the case of the Tuaregs in the Sudan. The advance of the nomadic Arabs from the Sahara into the lands of the more peaceable agricultural negroes to the south has been compared with the encroachment of the desert sands over some fertile grass-covered land along its border.

The more permanent dwellings often have flat roofs, and are built of stone or adobe, wood and vegetable products being scarce or entirely lacking. Sloping roofs are not needed, as the protection desired is not against rain, but against sun and wind. In hot, dry climates the flat roofs are generally used for sleeping at night. The houses are low, sometimes even partly underground, for better protection against the wind. When the people are on the move tents are taken, made of skins or, where the materials are obtainable, of thatch, palm leaves, or grass. The timber usually comes from the date tree. On the arid west coast of South America the Incas used

adobe bricks chiefly in the regions with least rainfall, and granite and porphyry on the rainier plateaus. Even the great Inca temples, built of massive stone blocks, had light thatched roofs, because but little protection against rain was necessary. In the Chilean desert many of the richest mines were discovered in the early days by men who were hunting for firewood or tending cattle.

The nights are often cool, and heavier clothing is worn than by day. Both clothing and food are simple, and are supplied chiefly from the flocks and herds, which are the desert inhabitants' most precious possession, or from desert plants, such as the date. Along the shores of the Persian Gulf, where there is no wood supply, even boats are made of date leaves. The dry desert air preserves rather than destroys. Sun-dried meat may become an article of food, as in the *charqui* of Peru. Livingstone and others have noted that the desert peoples of Africa are much less clean than those who inhabit the moister parts of the tropics. The lack of water, as well as the belief that water makes the skin sensitive to the heat, leads to a great lack of cleanliness. In Abyssinia, Nubia, and elsewhere, a kind of sand bath is substituted for the usual bath with water. Protection against dust and sun is found by covering the head and wearing a veil, as is done, for example, by the Tuaregs, who are completely covered with the exception of their eyes. Some tribes blacken their eyelids and their faces, just as is done by people in the Himalayas as a protection

against snow-blindness. During dust storms and high winds all protection may be inadequate, and death may result.

Utensils of all sorts are made chiefly of leather. In Nubia, as reported by Speedy, baskets are so closely woven of leather strips that they are fluid-proof. As these cannot be placed on the fire, milk is warmed by dropping red-hot stones into them. Many desert people become adepts at plaiting and weaving in leather. Well-digging is an occupation in which many of the Saharans have by nature been forced to become skilled. Here and there salt, nitrate, or borax deposits locally give an exceptional economic value to the desert, and furnish employment to many. Salt may become an important article of exchange. The amount of nitrate exported from Chile is determined largely by the weather and crop conditions of Europe.

That deserts have had a significant relation to religious ideas has been suggested by several writers. Ernest Renan points out that the desert is monotheistic, its uniformity suggesting a belief in the unity of God. The desert is conducive to a solitary, meditative life; even to a morbid and fanatical state of mind. Such conditions, it is believed, furnished good ground for the growth of such a religion as Mohammedanism. In his *Seas and Skies in Many Latitudes* (London, 1888, pp. 42–43), Abercromby gives two maps, showing respectively the areas of

Mohammedanism and the districts in Asia and Africa with a mean annual rainfall of less than ten inches. The maps are strikingly similar. The author adds: "Whether this distribution of a great creed is the result of chance, or of some deep connection between the tenets of that religion and climatic influences, I cannot say;—but still the relation is so remarkable that I have thought it well to bring the matter forward." The rain-ceremonies and rain-dances among the native tribes of central Australia; the Indian celebrations of the rise of water in the Peruvian rivers; the ancient Aztec sacrifices to the god of rain in Mexico, and other similar customs in tropical deserts, are natural in a region where water is of supreme importance. In one of the Australian rain-ceremonies, the men dance around a mimic water-hole, imitating the calls and motions of aquatic animals. These dances are reported as being carefully timed, by experienced individuals, to come at the seasons when rain is likely to fall.

The night is cooler and less dusty than the day, and is the best time for travelling. The camel, which can go long without food and water, is the natural beast of burden. Trade is still largely carried on by means of caravans, which require camels and drivers, and give employment to many men. The construction of railroads across these deserts will present the same difficulties which have already been met in the arid regions of the temperate zone. Ties dry

up and twist; the danger from fire is greatly increased, often necessitating fire patrols; fuel is expensive and must be imported, unless a poor local fuel, like sheep or llama dung, is used; water for men and locomotives must be brought in by water-trains, tank cars, or pipe line, or locally distilled, at considerable expense; cloud-bursts sweep away bridges and tracks; the number of working hours by day is reduced by the heat; drifting sands cover the track and must constantly be shovelled off; the blowing sand hinders seeing, and increases friction and wear on the rolling stock; watchmen to guard against accidents from blowing sand on the track must be employed; proper non-dusty ballast is difficult to secure; all lumber must be brought from moister regions. On the other hand, the trade wind deserts are, on the whole, healthy regions. When the Sahara and the Australian desert are bridged by railroads, and when the South American coastal desert is traversed by a longitudinal line of track from north to south, the relations of these great arid regions to man will inevitably be greatly changed.

Trade Belts at Sea. At sea, the trade wind belts are closely related to man through their control over sailing routes, and over voluntary and involuntary migrations. A glance at any pilot chart will show that all sailing routes which pass through the trade wind belts in any ocean are determined by the course of these winds. The route from Europe to India furnishes a good example of the advantage that is

taken, by mariners of the present day, of the prevailing wind systems of the world. In former times a vessel was kept close in along the west coast of Africa, amid calms and adverse winds, and then, after passing the Cape of Good Hope and leaving Mozambique, she waited for the blowing of the south-west monsoon, with which she continued her voyage to India. In 1500, Cabral sailed from the Cape Verde Islands out into the open sea with the north-east trades, avoiding the African coast. Keeping far to westward he discovered Brazil; continued across the south-east trade, rounded the Cape of Good Hope with the westerlies, and then proceeded up the east coast of Africa as had previously been the custom. In the 17th century the Dutch struck off on the new route from the Cape of Good Hope, making their easting in the prevailing westerly winds of the South Indian Ocean, and then sailing up to India with the south-east trade. The passage across the equatorial belt of calms (doldrums), which was formerly much dreaded, is now so carefully worked out that vessels may cross where the belt is narrowest, and where there is therefore the least danger of delay.

Steady winds like the trades certainly tempted the early navigators to put to sea. The famous voyage of Columbus, when he discovered America, was facilitated, if not made possible, by the north-east trade. The easy outward voyages of the early Spanish adventurers and colonists took them naturally to that portion of the Americas where they found climates in

which they and their descendants could live, while to the Anglo-Saxon originally fell the North American continent, with its more rigorous climate. The monsoons of India have, from the earliest days of trade with the East, been important agents in aiding commerce. In the Mediterranean, the Etesian winds —the northward extension of the trade—favoured early commerce. The migrations of the Malays to the Melanesian Islands, of the Polynesians, and of other Pacific islanders, found their occasion and their possibility in the prevailing winds of those latitudes. The islands from the Philippines to the Gilbert Islands are in the north-east trade and from the Moluccas to the Society Islands in the south-east trade. Thus intercourse and migrations are easy. In the archipelago of the monsoon belt south-east of Asia trade depends largely upon monsoons. An interesting case is cited by Ratzel, on the authority of von Maltzan. Two small ports, Bîr Ali and Megdaha, lie opposite one another on the southern coast of Arabia, in a small bay. The former is protected on the west, and the latter on the east. Hence the former is sought by shipping in summer, and the latter in winter. Both places have grown and really make one town, the officials and many of the inhabitants moving twice a year with the seasonal change of wind. The war expeditions of the native tribes of this great island region have always been governed by the monsoons. In many places to-day native boats do not venture to sea at the height of the monsoon. In

the discussions regarding the relative advantages of the Nicaragua and Panama Canal routes, much emphasis was laid upon the prevailing winds in the two cases. Many of the optimistic predictions concerning the use of the Panama Canal by sailing vessels did not take account of the calms and variable or adverse winds to be encountered before entering and on leaving the canal, which necessitate transportation by steamer, or at least some towing of sailing vessels.

To leeward of the west coast of Africa navigation is not infrequently interfered with by the so-called "tornadoes," which move westward off the land, and by dust-storms, which obscure the air and delay progress.

Tropical cyclones at certain seasons and in certain parts of the trade wind belts at sea not only damage shipping, but often devastate towns, bridges, and crops, bringing starvation, poverty, and not infrequently pestilence as well, owing to decaying animal matter, or fish thrown up by the sea. Thousands of lives have been lost as the result of such disasters. The Pacific islands are particularly unfortunate in this respect. The storm waves produced by these cyclones are especially severe at the head of the Bay of Bengal. Native huts are easily blown over by the cyclonic winds, and it has been pointed out that the huts elevated on high posts in New Guinea, and swaying with the wind, furnish good evidence that the district in which they are found is not visited by

tropical cyclones. In some places, Mauritius, for example, houses are provided with shutters to be used in case of a cyclone, and in many places the natives have resistance to cyclones in mind when they build their huts. In time, buildings must be erected in the tropics which will withstand these storms better. Worcester reports of the Philippines that in order to save the banana trees from destruction by typhoons, some of the natives cut off all the larger leaves when the approach of a typhoon becomes evident.

Monsoon Districts. Of the monsoon districts on land, India is the largest example. The two seasons are strongly contrasted. The success or failure of the crops depends upon the amount, distribution, and time of occurrence of the summer monsoon rains. Famine follows when these rains are deficient or unfavourably distributed, with terrible suffering and the loss of thousands of lives among men and cattle. Lately the government of India, at great expense, has undertaken relief works during times of famine, including irrigation works. The amount and regularity of the water supply is the chief factor in determining the density of population in India.

Travel and transportation in monsoon districts depend closely upon the season. During the rains, the roads are likely to be bad or impassable, and landslides and washouts are common. In the Philippines the mud is so deep that sledges are used instead of wheeled vehicles. Communication may be entirely interrupted by floods. Campaigning under such

conditions is extremely difficult, as was abundantly proved during the American occupation of the Philippines. Horses, and even water-buffaloes, were often unable to haul the guns, one of the difficulties with the buffaloes being their need of a mud bath in the hottest part of the day. During the early part of the American campaign in the Philippines the success of the American army was achieved in the dry seasons, the natives gaining the upper hand, or at least making the most progress, during the rains, when conditions were hardest for the white men.

Native dwellings are adapted to the different seasons, as on the island of Mindoro, where the Mangyans erect simple shelters of rattan and leaves wherever they happen to be in the dry season, while in the rainy season the dwellings are more elaborate and more secure. The rain hat and coat of the Filipinos; the preparations made in north-western Mysore, on the summit of the western Ghâts, in laying in provisions to last during the long rainy season, as if it were for an extended voyage at sea; the general use of punkahs, tatties, grass mats, etc., for cooling purposes during the hot and dry season in India and Persia, these being often wet, and kept in motion by coolies; the habit of closing houses during the day and of staying indoors during the hottest hours,—these few cases may suffice to illustrate the control of climate over the life of man in the monsoon belts.

Tropical Mountains. Their "temperate" climates

have given many tropical mountains and plateaus a deserved popularity, and the increasing settlement of the tropics by white men and women will constantly tend to bring such elevations into greater use. Under these conditions the usual law of the decrease of population with increase of altitude is locally reversed, at least up to a certain height. Mountains within the polar zones do not increase the habitable parts of the earth's surface. Mountains within the tropics certainly give white men and women a larger area and more comfortable conditions of habitability. There is observable a tendency for the altitude of human settlements to increase from polar latitudes towards the equator. In the far north man lives close to sea-level; within and near the tropics there is often a large population at considerable altitudes, as in the Himalayas and on the Andean plateaus. In parts of South America at the present day (*e. g.*, Colombia) the plateaus are the chief seat of the Spanish and Spanish-Indian population, and the lowlands are occupied by the negroes. The talk of removing the Brazilian capital from Rio de Janeiro to a more elevated location in the interior province of La Goyaz, and the government offices of the Italian colony of Eritrea from Massowa, on the Red Sea, to the high plateau of the Hinterland, shows the upward tendency of the white man in the tropics. On the other hand, the production of sugar-cane, coffee, and other valuable products will obviously lead more and more to the development of the lowlands under white control.

To the greatest altitudes man is attracted by mineral wealth, and lives under very hard conditions. Some of the Tibetans live more or less underground, and melt ice in order to secure water. High mountains within the tropics show a vertical succession of climates from tropical at their base to eternal snow on their summits. A very striking illustration of this may be secured by a passenger who travels over the famous Oroya Railroad, in Peru. This road runs from sea-level to a height of 15,665 feet, and then descends again to about 12,000 feet. The first part of the journey is through fields of sugar-cane and cotton; at about 5000 feet a zone of fruit trees is passed through; at 10,500 feet there is a district famous for its potatoes, where little else is grown; above this, the altitude is so great as to preclude the growth of anything but grass. At the highest point reached, the snow lies on the mountain summits throughout the year, and the traveller may enjoy a snowstorm in the middle of summer (December–February). In the interior valley, farm produce is again seen growing. This whole succession of climates may be passed through in the short space of ten hours. Tropical mountains may thus produce temperate zone crops. In the deserts, mountains may be covered with forests and other vegetation, by reason of the rainfall which they provoke. Here man naturally settles, finding water and perhaps favourable conditions for agriculture. Such mountains become "islands" of denser population, as do the streams which run out

from them to wither away in the desert. In Dar Fur, in the eastern Sudan, most of the inhabitants live in or near, and in close dependence upon, the Marra Mountains. Kilimanjaro, in equatorial Africa, rises as an island above the surrounding steppes, and is in the centre of a large population. At the southern foot of the Atlas Mountains there are three ethnological zones, from the nomadic desert-dwelling Tuareg to the Berber tribes scattered in the mountains, with a denser population in the strip of oasis between.

The permanent physiological effects of tropical mountain climates have not as yet been carefully studied. Junghuhn has noted an improvement in the physical condition of people who live at altitudes of 6000 to 6500 feet in Java; in Africa, the Zulus and Hovas have been instanced as furnishing an example of the strengthening influence of mountain climates, and other cases are cited of mountain tribes who rob, or rule over, lowland tribes. On the other hand, in Mexico, Jourdanet has described the anæmic condition, poor physical development, low birth-rate, and short lives of the inhabitants of the plateau of Anahuac, and Charnay noted the fact that the Indians who brought sulphur from Popocatepetl fell off in bodily vigour at an early age. Prescott, however, in his *Conquest of Mexico,* noted that the physical development of the Tlascalans on the plateau was better than that of the people of the lowlands. The enlarged lung-capacity of the inhabitants of the lofty

punas on the west coast of South America has naturally been attributed to the effect of the rarefied atmosphere. It is interesting to observe that it often happens that plateau and mountain peoples sicken and are unable to work when taken to sea-level, and the same thing is true of lowlanders who are taken to considerable altitudes. The Aymara Indians of Peru, when taken down to sea-level by the Spaniards, could not stand the change. Great difficulty has been found, as pointed out by Spence, in securing labourers on coffee plantations at altitudes of 4000 to 6000 feet in South America. Labourers from greater altitudes and from near sea-level alike become ill and unfit for work. Additional examples might be cited.

Special mention may be made here of a peculiar relation between climate and man on certain lofty tropical mountains, which are snow-capped, and which furnish a supply of snow or ice for refrigerating purposes in the towns below them. Thus in Ecuador, snow is carried to Quito from the upper slopes of Pichincha; to Riobamba and Ambato from the slopes of Chimborazo. Ambato used to supply its brewery with snow from the same mountain. Guayaquil was formerly supplied with ice in the same way. In Colombia, Popayan, in the department of Cauca, is also supplied with ice and snow from neighbouring mountains. In parts of Syria, also, snow, gathered in the mountains, is packed firmly in pits dug in the ground, and covered with straw

and leaves. It is later sold. In Mexico, snow is carried from the summit of Colima to the towns on the hot plains below. Howarth notes the discovery of an "ice factory" in one of the highest valleys in Oajaca, in Mexico, at an altitude of 8000–9000 feet. In this case the active nocturnal cooling by radiation is the effective climatic factor at work. "The ground was covered with a vast number of shallow wooden troughs, which are filled at nightfall with water from the dividing stream, and during the nights of the winter months this becomes covered with a film of ice not more than one-eighth of an inch thick. In the morning this is removed and shovelled into holes in the ground, and covered up with earth, after which it consolidates and is cut out in blocks and sent down by mules, where there seems to be a ready market at all seasons." On the high veldt the Boers keep their provisions by letting them cool outdoors at night. The peculiarly dry climate of the plateaus of the west coast of South America is due to the leeward position, west of the Cordilleras. The Incas preserved their dead by allowing them to mummify naturally in the dry, rare atmosphere.

The construction of railroads at high altitudes in the tropics, as on the west coast of South America, has been delayed and rendered expensive by mountain sickness, and by man's decreased efficiency for work; by cloud-bursts, flooded rivers, and landslides. In the higher passes over the mountains, diurnal winds are sometimes met with of such velocity that

travelling by day is impossible at certain seasons. Moritz Wagner has described the down-cast winds from the snowfields near Quito, which at certain times are of such violence as entirely to interrupt travel across the Chimborazo passes. Darwin and many others have noted the diurnal variation in the height of water in rivers fed by melting snow. Such streams are easiest to ford in the early morning, when the water is lowest.

CHAPTER IX

THE LIFE OF MAN IN THE TEMPERATE ZONES

Climate and Man in the Temperate Zones: General—Northward Movement of Civilisation in the North Temperate Zone—Present-day Migrations within the Temperate Zones—The Continents and the Temperate Zones—Differences between Northerners and Southerners—Variety of Conditions in the Temperate Zones: Classification—Life of Man in the Forests of the Temperate Zones—Forest Clearings—The Steppes—Climates and Crops in the Temperate Zones—The Deserts—Mountains—Climate and Weather: Some Mental Effects—Climate and Weather and Military Operations—Railroads—Transportation by Water—Various Effects of the Weather.

Climate and Man in the Temperate Zones: General. Intermediate in location, in mean temperature, and in their physiological effects, the temperate zones, whatever was the condition in the past, are to-day clearly the centre of the world's civilisation, as they have also been the scenes of the most important historical developments for several centuries. From the temperate zones have come the explorers and adventurers of the past, and are coming the exploiters and colonisers of to-day. In the occurrence of the temperate zone seasons lies much of the secret—who can say how much of it?—of the energy, ambition,

self-reliance, industry, thrift, of the inhabitant of the temperate zones. Guyot did not exaggerate when he wrote:

> In the temperate zones all is activity, movement. The alternations of heat and cold, the changes of the seasons, a fresher and more bracing air, incite man to a constant struggle, to forethought, to the vigorous employment of all his faculties. A more economical Nature yields nothing except to the sweat of his brow; every gift on her part is a recompense for effort on his. . . . Invited to labour by everything around him, he soon finds, in the exercise of all his faculties, at once progress and well-being.

The monotonous heat of the tropics and the continued cold of the polar zones are both depressing. Their tendency is to operate against man's highest development. The seasonal changes of the temperate zones stimulate man to activity. They develop him physically and mentally. They encourage higher civilisation. A cold, stormy winter necessitates forethought in the preparation of clothing, food, and shelter during the summer. Carefully planned, steady, hard labour is the price of living in these zones. Development must result from such conditions. In the warm, moist tropics, life is too easy. In the cold polar zones it is too hard. Temperate zone man can bring in what he desires of polar and tropical products, and himself raises what he needs in the great variety of climates of the intermediate latitudes. Near the poles the growing season is too short. In the moist tropics it is so long that there is

little inducement to labour at any special time. The regularity and the need of outdoor work during a part of the year are important factors in the development of man in the temperate zones. Where work is a universal necessity, labour becomes dignified, well-paid, intelligent, independent.

Behind our civilisation there lies what has been well called a "climatic discipline,"—the discipline of a cool season which shall refresh and stimulate, both physically and mentally, and prevent the deadening effect of continued heat. On the other hand, a very long winter is about as unfavourable as a very long summer. If outdoor work is seriously interrupted, progress is retarded. Buckle based certain too broad generalisations on this consideration, and saw in it an explanation of similar national characteristics among peoples whose outdoor work is interrupted for the same length of time. But it is clear that the length of the farming season is a large factor in controlling the return from the soil, the kind of work done, and the manner of doing it. It is not surprising to learn that the difficulty of keeping farm labourers through the long winter has in the past been a handicap in western Canada, and that it was urged against the abolition of slavery in Russia that it would be impossible, without some form of compulsion, to keep farm-hands through the winter.

Northward Movement of Civilisation in the North Temperate Zone. The gradual migration of the centre of civilisation away from the tropics, and the

highest development of the human race, not where life is easiest, but in extra-tropical latitudes, are significant.

"Slowly but surely," as Benjamin Kidd says [*Control of the Tropics*, 51–52], "we see the seat of empire and authority moving like the advancing tide northward. The evolution of character which the race has undergone has been northwards from the tropics. . . . Underneath all the outward national quarrels of Europe there has been going on for centuries what is really a struggle between what we might call the Latin type of civilisation, represented by the southern races, and that type of civilisation which has been developed in northern Europe."

From the Mediterranean region, where the world's civilisation, its commerce, and its power were long centred, westward through Spain and Portugal, the migration continued farther and farther north in Europe, until Holland and then England became the dominant power. From lands of more genial climates to lands of colder and longer winters, but also of the most active and energetic races, the migration has taken place. The advance of Christianity, from its origin in the subtropical belt of Eurasia into higher latitudes, has been pointed to as another illustration of the same tendency. Together with this northward tendency of civilisation there has run through the past an equatorward movement, already noted in the case of the tropics, of the stronger peoples of the north toward the milder and more genial southern latitudes, involving historical events of great importance.

Present-day Migrations within the Temperate Zones. Within the north temperate zone especially, and also across from the north to the south temperate, vast, peaceful migrations are taking place, determined largely by climatic considerations. From Europe and Asia to the United States alone, a million people a year are now migrating. These immigrants have shown marked tendencies to settle where climate, soil, and occupations are most like those of their old homes, although the fact that most of them land at one port on the eastern seaboard, the concentration of industries in certain sections, and other controls, have operated very effectively to counteract and interfere with this tendency. Scandinavians, for example, have gone largely into the north-west; and in the future the southern parts of the United States will doubtless have a large Latin population, chiefly of Italians and Spaniards, who will there find homes and occupations in climates best suited to their needs. Canada has grown slowly, partly on account of the repelling effect of her long, cold winters and her generally severe climate. Of late years, however, the rapid settlement of farming lands in the United States, the attraction of free, or cheap, lands in western Canada, and the success which has been attained in raising wheat and other crops during the short but favourable Canadian summer, have combined to induce a considerably increased immigration of farmers from the United States, and of Europeans, into Canada. This migration within the temperate

zone is peopling Canada, South Africa, and Australia with the same stock that occupies the homeland of the British Isles. Therefore institutions and government essentially similar to those at home are possible in these colonies of England beyond the sea. The case is very different in tropical climates, as has been seen. Russia will later be found to gain great strength from the fact that she has expanded eastward within the same zone.

In Argentina, the climatic control of migrations is even more clearly marked than in the United States, the Italians tending to settle towards the north, where the climate is most like their own, while the races from northern Europe show a tendency towards the south.

It is interesting to observe how immediately controlled by the special weather conditions of even one season these voluntary migrations may be. Years of sufficient rainfall and abundant crops in the United States are always followed by a larger immigration. A failure of crops in Europe, whether it be of wheat in one country, or of fruit in another, or of potatoes in another, resulting from drought, or storms, or excessive rainfall, always promotes a larger exodus from the country concerned. There is, furthermore, a considerable seasonal migration across the Atlantic. Thousands of Italians come to the United States in the spring to work during the warmer months, when farm and outdoor labourers are in demand, and return to the milder climate of Italy for the winter.

Similarly there is a seasonal migration, also chiefly of Italians, to Argentina at harvest time. The possible effects of the advancing ice-sheet of the glacial period in producing forced migrations equatorward may be mentioned, in passing, as another example of climatic controls over human movements.

There is also an interesting tendency westward, observable not only in the westward "course of empire," but in the advantages enjoyed, in the belt of prevailing westerly winds, by those who live in the western quarters of cities. The "west ends" are usually the most fashionable and the newest sections of these cities, while the quarters to leeward, the "east sides" and "east ends," are inhabited by the poorer classes. Ratzel points out that among the Arabs of Syria the tent farthest west is that of the sheik.

The Continents and the Temperate Zone. Europe is well situated climatically, being almost altogether in the temperate zone, and open to the ocean on the west, so that nearly all parts of it are well watered.

Asia is an overgrown continent. Much of it is in the temperate zone, it is true, but the interior is so far from the sea that the climate is severe and the rainfall very deficient. This condition of hopeless aridity is depressing, in the extreme, and this region is prevented from becoming thickly populated or important on that account.

Most of Africa is within the tropics. Its plateaus will furnish considerable areas not wholly unfavour-

able for white settlement. The southern part of Africa is just within the marginal sub-tropical belt of the south temperate zone. The same is true of Australia.

North America is widest in the temperate zone, which is one of its greatest assets. It suffers from the extreme cold of its winters in the north, and from the rain-shadow effect of its western mountains, which gives the interior basin and part of the western plains deficient precipitation.

South America is widest within the tropics. Its west coast is peculiar in having the tempering influence of high plateaus in the interior and of a cool ocean current along the coast. Its southern portion tapers off into the south temperate zone. This part of South America, and the scattering islands of the ocean area in these latitudes, suffer from an equable but cheerless, depressing, and inhospitable climate. The forlorn natives of Tierra del Fuego, most inadequately clothed and housed; living on shell-fish and other sea-food; with the poorest kind of utensils and implements; nomadic in habits; shifting their single fur garment from side to side according to the wind direction—these furnish a good illustration of man's mastery by a climate which Darwin described in the following words: "It would be difficult to imagine a scene where he (man) seemed to have fewer claims or less authority. The inanimate works of nature—rock, ice, snow, wind, water—all warring with each other, yet combined against man—here reigned in

absolute sovereignty." The Falkland Islands, by reason of their dull, moist, cool, and windy climate, produce nothing but a few poor potatoes and some berries. All other food, excepting mutton and beef, has to be imported. Very different is the life of man in the same latitudes of the continents in the northern hemisphere, where a more severe climate has given better opportunity for man's development.

Differences between Northerners and Southerners. There are certain broad, distinguishing characteristics of man in the temperate and tropical zones, in determining which it is reasonable to believe that climate has played a part. Similarly, there has been a natural tendency to attribute certain differences between northerners and southerners in the temperate zones to a difference in climate. There is an opinion that the former, living in a duller, harsher climate, with long and dreary winters, are more serious, more industrious, more enterprising, and act after more mature deliberation, than the latter who, reflecting their brighter skies, are more cheerful, more emotional, more impulsive, more genial, more generous, but also less energetic, and more easy-going. It has recently been pointed out by Professor Jerome Dowd that labour organisations in the southern United States are hampered by their liability to hasty, ill-advised action. The northerner must exercise more forethought, care, industry, and prudence; he has to work harder, and is usually better paid than the southerner.

These national differences are proverbial between northern and southern Germans, French, Spanish, Russians, Italians, Arabs, and other peoples. The influence of climate has likewise been traced in the sad, even pessimistic tone of much of the northern literature, and in the gravity and melancholy of modern northern music, as well as of the older northern folk-songs.

The question is a very complex one, often much complicated by actual racial differences between the northern and southern people of the same country. Yet even racial distinctions are more or less directly traceable, in many instances, to climate. Thus a recent writer, Gustave Michaud (*The Century,* March, 1903), has told us that the Baltic race

is probably the result of the natural selection by a cold climate over emigrants who belonged to the primitive Mediterranean race, and who gradually moved northward. Many of their mental as well as their physical characteristics find an explanation in that hypothesis; those individuals who, through lack of ingenuity, foresight, or activity, were unable to meet the requirements of a severe winter, perished generation after generation; their posterity was constantly decreased, and the posterity of the active, energetic, and thoughtful was thereby relatively increased.

Sir Archibald Geikie, in his *Scottish Reminiscences,* has emphasised the climatic influence in producing the grim character of the Scot in the following words: "The gloom of his valleys is deepened by the canopy of cloud which for so large a portion of the

year rests upon the mountain ridges and cuts off the light and heat of the sun. Hence his harvests are often thrown into the late autumn, and in many a season his thin and scanty crops rot on the ground, leaving him face to face with starvation and an inclement winter. Under these adverse circumstances he could hardly fail to become more or less subdued and grim."

Draper emphasised the important historical consequences of the difference in the characteristics of northerners and southerners in the United States, which he attributed largely to climate, and which found expression in the Civil War. The climate of Virginia, somewhat more genial than that of New England, may not unreasonably be supposed to have made its mark upon the early settlers in the former state, while the Puritans were struggling against the harsher forces of nature in the north-east. The Boers in Africa have developed along lines different from those of the Dutch in the United States. The climate, soil, and crops of the southern states made negro labour highly desirable, even necessary, and the presence of the negro involved some form of compulsion—slavery.

Variety of Conditions in the Temperate Zones: Classification. The temperate zones embrace so great a variety of climates that it is not practicable to consider the relations of climate and man according to any rigid climatic scheme. It is simpler, as well as more logical, to consider the typical examples here

selected according to the broad classification of forests, steppes, and deserts. This is essentially a scheme which depends upon rainfall, and is, therefore, a reasonable one for adoption by those who approach the subject from a climatic standpoint.

Life of Man in the Forests of the Temperate Zones. The forests of the temperate zones are chiefly coniferous on highlands and in colder climates, and deciduous on lowlands and in lower latitudes. They are found, as a rule, where the mean summer temperature is over 50°, where the rainfall is reasonably heavy, and is well distributed, and where soil and other factors are not unfavourable. Forests are characteristic at the present time of the rainy west coasts of the continents, as in southern Chile and on the northern Pacific coast of North America; of much of the interior of North America and of Siberia; of the Scandinavian highlands. On the north, the great forest belts merge into the tundra through a zone of scattering trees and stunted bushes. On the south, they grade into the open steppe country of the continental interiors. Much of the temperate zones, except where too dry, was originally forest-covered, but the trees have been gradually cleared away and an open country, devoted to agriculture, or the seat of modern manufacturing and industrial settlements, has taken their place. The southern portions of the great forest belts, because of their more favourable climates, are better adapted to agriculture than the northern portions, and are therefore first attacked,

as is now the case in Siberia. The more severe climate of the latter, and their greater inaccessibility, will help to preserve them from destruction for farming districts, with the primitive life of the trapper and woodsman as their distinguishing characteristic. The temperate zone forests, hampering man's movements, preventing dense population, and being replaced by more profitable farming country, have thus gradually been driven back from the lowlands onto the mountains and highlands of Europe, where scattering forests alone remain. These are in most cases protected by government. In the United States, similar clearing has been going on, with similar consequences. Many of the forests which still remain on the mountains have been set apart as national forest reserves, in order that they may serve as regulators of water supply and as parks for future generations. The slow spread of the white population in the United States, from the originally forested eastern section where it so long had its seat, to the open country farther west, was certainly in part due to the great difficulty which the early settlers experienced in clearing away the forests which they found on the Atlantic slope. A larger population, better means for clearing the forests, and improved transportation, later changed this.

The foregoing statements must not, however, lead us to jump at the conclusion that all open areas were once forested, and thus to infer that a supposed de-

forestation, which may never have taken place, has produced a change of climate which has not been proved. Many such cases have been reported for the sub-tropical belt of the Mediterranean, and for South Africa, but sub-tropical climates, with their dry season and light rainfall, are not favourable to heavy forest growth. It is significant that the ancient Greeks imported their most valuable woods from the north.

Before the forest cover—the natural product of soil and favourable climate—is cleared away, man is chiefly occupied in hunting fur-bearing animals in the colder latitudes; in fishing, and in lumbering. The latter occupation is greatly facilitated by the winter snows in northern latitudes, which make sledging easy, and by the spring freshets, which carry the logs down to the saw-mills. Where there is no snow, the difficulty and expense of getting out the timber are usually considerably greater. The woodsman's life is primitive and hard, and retains many nomadic traces. The resort to "the woods" for hunting and fishing by a good many people from the north temperate zone for a part of the year brings for a time a relief from the restraints of civilisation, and the rest that comes from a return to more primitive conditions of life. There is a considerable seasonal change of occupation among the lumbermen of the northern United States and of Canada, many of them becoming farmers or sailors in summer. Industries which depend upon a supply of lumber, such as paper and

pulp mills, shipbuilding, furniture, carriage and barrel manufactories, and the like, are often found on or near the streams down which the logs are floated. The simple log hut of the early settler in the American forest is one of the most typical forest dwellings, which are naturally built of wood. The Japanese houses of bamboo and wood are not unsuitable in a region of tree-growth, of a modified continental climate, and of earthquakes. Forest fires are often very destructive, not only to the trees themselves but to the wooden dwellings in the forest.

Fish and game are the natural food of forest peoples, and clothing is chiefly made of fur or leather. Forest products are brought to the edge of the forest for sale or exchange. Thus the trappers in North America played an important part in the early history of that continent. Settlements, which were originally trading posts, grew up along the streams, and later became towns and cities. Almost all the large cities of the north Pacific coast of the United States owe their prosperity to the lumber industry, and the same is true of other cities in or near the forested portions of the country east of the Rocky Mountains.

The dense Alaskan coast forests, which extend far north where the moisture, even without high temperatures, is favourable to them, have to-day certain noteworthy effects on the native Indian tribes who live along their borders. The density of vegetation and the difficulty of agriculture force them to turn

to the sea, on which they spend most of their time, on which they travel, and from which they obtain their food. They become expert canoe-builders, sailors, and fishermen; are finely developed in the upper portions of their bodies, but spend so much of their life in their boats that they dislike walking and are poor hunters and porters. Their food, and the material for some of their utensils and implements, they secure from the sea. They wander about to different fishing-grounds, living a more or less nomadic life; some of them even going into the State of Washington in harvest-time. It is an interesting fact that the best canoes are built by the Indians who live in the most stormy locations, and these same people are also the best sailors. On the coasts of southern Chile the dense forests have kept the population close to the sea; have made clearing for farming difficult, and have resulted in making lumbering, hunting, and fishing the chief occupations. Darwin reported of this region that the constant rains keep everything so wet that to clear the forest by fire is almost impossible.

Forest Clearings. Man gradually makes clearings in the virgin forest, and then cultivated crops take the place of the natural tree-cover, except where extremely favourable conditions for tree growth, or poor soil, or steepness of slope, make forests more profitable than agriculture. At present, much of the population of the civilised world lives in such clearings. Where the clearings are small, as in parts of

Scandinavia, the life is simple, combining lumbering, hunting, and fishing of the forest with agriculture. If the sea is near by, boat-building, as in Norway, also becomes an important industry, with deep-sea fishing and sailing. Simpler industries, like wood-carving and match-making, are also found. Communities are scattered, and are largely independent of one another. Each community is self-supporting, and each individual is more or less of a "Jack-of-all-trades." Isolated clearings, where civilised man is making the first inroad into the primeval temperate forest, may still be seen in several parts of North America, and will become increasingly common in the Siberian forest belt.

With the destruction of the forest and the growth of agriculture, with settled places of abode and a reasonably certain food supply following steady, careful, and intelligent labour, comes the gradual accumulation of a surplus, and the increasing diversity of interests and occupations which characterise the modern, highly civilised community. Here we find a very complex life, with industries and manufactures of all sorts; where raw materials and supplies are imported from other lands and climates and exported to them, and where the immediate climatic control often becomes difficult to see. It is under such conditions that civilised man lives to-day, using the products of the forest, the farm, the mine, the sea, the lake, the river; making the most of his opportunities; overcoming more and more the disadvantages

of his immediate surroundings. It remains a fact, nevertheless, that one of the most important controls in determining the location of modern industries, next to nearness to materials and markets and water-power, is climate.

The Steppes. In the intermediate belts, between the heavier rainfall of the forested districts and the deficient rainfall of the deserts, come the grass-lands of the temperate zones, commonly known as steppes ("unwooded tracts in middle latitudes, of considerable extent and covered with useful vegetation"). These are found where the rainfall is small because of distance from the sea, or by reason of the rain-shadow effect of enclosing mountains, and over broad, more or less level topographic areas, of fairly uniform climatic conditions. The general severity of the climate, the small rainfall, the shortness of the growing season, and other factors, such as high winds, favour grass rather than tree growth. The central Asiatic plateau, except where so arid as to be a true desert, with uniformity of climate and of population, is the great steppe region of the world. Southern Siberia, southern Russia and Hungary, and parts of Arabia, Persia, and Asia Minor belong to this same area. The Great Plains between the Rocky Mountains and the 100th meridian are classed as steppes, as are the grass-lands of eastern temperate South America. The Asiatic steppe is extremely unfavourable, so far as occupation and development by man are concerned. At the centre of a great

overgrown continent, with the trade of the world naturally passing around it, largely by water, rather than across it; with few rivers and deficient precipitation, the effect on man, whatever may have been the conditions of the past, is such as to depress, retard, overcome him. Civilisation there lags behind that in the rainier lands of the temperate zone. The grasslands of North America, it may be noted, have the advantage of being a narrow belt between two well-watered and fertile regions. The dry season scorches the grass and dries up the rivers; the spring rains bring out the carpet of grass and flowers. Winter storms and cold sweep over the steppe, often fatal to man and beast.

The primitive inhabitants of the Eurasian steppe, like the Kirghiz, Mongols, Kurds, are nomads, moving about during the summer in search of water and pasturage for their animals. Their migrations often take them to the higher country, where there is more chance of finding water, and where the grass is better. A dry year forces migration into the adjacent rainier districts. In the colder months the people settle down in more permanent abodes. Thus also we find the inhabitants of the Hungarian plain townspeople in winter and semi-nomadic farmers in summer. Professor W. M. Davis has noted the use of small farm-houses on wheels in Bosnia, which "are drawn forward on the plain in the dry season, so as to stand near the pasture fields; and back again towards the higher margin in the wet season." The

driving of cattle from Argentina across the mountains into Chile during the dry season is another instance of seasonal migration in search of pasturage in grass-lands.

The primitive steppe-dweller depends on his flocks and herds for his food and clothing, and for his tent-coverings and utensils. From their wool, or hair, he makes his cloth, or carpets. The summer dwellings of the Asiatic steppe-dweller are usually felt tents, adjustable, portable, skilfully constructed. These, with simple household goods made principally of leather, at once the most available and most useful material, are easily transported from place to place. In winter, encampments are carefully selected where there are water and grass, and where hay is collected. The winter dwellings are better built, of the willows or reeds found along the streams, and the animals are sheltered against cold and storm. As on the coastal desert of South America, so here, a common fuel (in winter) is the dried dung of animals. Horses are a precious possession, essential to the wandering life of people some of whom call themselves The Horsemen (Kazák). The trade of the Asiatic steppe is carried on with China on the one side and Russia on the other. Hides and other products obtained from the flocks and herds are exchanged for tea, flour, opium, clothing, etc. Independent, conservative, and proud, the natives retain their traditional customs, and resist the encroachments of civilisation. The life of man in

steppe and in tundra has many points of resemblance, but the steppe is the more favourable to improvement.

The early life of the white man on the Great Plains of North America has been similar in many ways to that on the Asiatic steppes. Immense herds of cattle have grazed at will over a vast extent of territory, driven here and there in search of pasturage and water, and tended by semi-nomadic cowboys spending most of their lives in the saddle. The gradual destruction of the natural grass forage by over-stocking, and by the introduction of sheep, has not infrequently led to armed conflicts between those in charge of different herds of cattle. The United States has also illustrated what has been observable in other lands, viz., the conflict between the divergent interests of those who want grass-lands for agriculture and those who want them for grazing. In North America the conflict was not waged with bloodshed, but history furnishes examples of the warlike encroachment of pastoral nomads into the peaceful farming communities on the borders of the steppe. China, for example, was invaded by steppe-dwellers, as was Europe at one time; even to-day, Kurds and Armenians are struggling in a similar way. In the United States, the facility of communication and the rapid advance of population from the east have led, in recent years, to a considerable change in the use of certain portions of the Great Plains steppe region. After an almost exclusive use of these plains for cat-

tle, farming without irrigation was tried over their central portion in the latter part of the decade 1880–1890, during and closely following a series of years with a rainfall somewhat above the average. The experiment proved to be a failure when a series of drier years followed. Since then, local irrigation by means of wind-mills has been introduced to a considerable extent, and diversified farming under irrigation, with cattle-raising on a much smaller scale than formerly, has been found to be a far more profitable undertaking than farming on a large scale without irrigation. The cattle are fed, when necessary, with alfalfa or other forage raised for that purpose; are bred under supervision, and are protected against the severe winter storms and cold. The climatic limitations of the Great Plains are now clearly recognised. By far the greater portion must forever remain pastoral, but where irrigation can be practised, farming and cattle-raising together are more profitable than either alone. Irrigation, together with the proper preparation of the soil and the planting of crops suited to the climate, has worked a complete change in the appearance and in the economic value of many parts of the Great Plains. The large modern cattle ranch in the western United States is very different from the wandering cattle herd of a few years ago. There are summer and winter ranges for the stock, the winter range being sheltered as much as possible. On a well-equipped ranch, a barometer is watched as carefully as on board ship.

When a storm is expected, the sheep or cattle are brought to shelter if possible, or if not, are driven to windward, so that they will be driven home by the storm. In Australia the grass-lands have been occupied by British sheep-owners, employing native stockmen, and the conditions of life are much like those of the ranchmen on the Plains of North America.

Obviously, wherever irrigation is possible, steppes become more valuable for farming than for grazing. There is a limit to the water supply, whether that come from rivers or from underground, and an increasing population, with increasing demands for water, must in time reach the limits of the supply. In many of the western states of the American Union, where with increasing population the need of irrigation has been felt more and more, much litigation has arisen concerning the right to water. The difficulties have come in great measure from the fact that the laws were imported from rainier regions, where irrigation was unnecessary. On the Asiatic steppes, Russian influences are encouraging irrigation and agriculture. As a rule, the steppes of the temperate zone have been cultivated where settled by people who had formerly been farmers in more humid regions.

The wide expanse of the steppes, with their unobstructed surface, situated as they usually are in the extreme climates of the continental interiors, exposes them to sudden temperature changes. The far-

reaching sweep of cold storm winds from higher latitudes, such as the cold norther or blizzard of North America and the buran of Siberia, may destroy thousands of cattle in a few hours and not infrequently human lives as well. Depressing hot winds from lower latitudes, which carry high temperatures far poleward, sometimes injure crops by their heat and dryness. In dry times, fires once started have a free sweep over the open steppe country.

Climates and Crops in the Temperate Zones. The variety of climates found over the temperate zones, especially in the northern heimsphere, is very large, ranging from the modified marine climate on the west coasts to the extreme continental of the interiors and the modified continental on the east coasts, and also varying greatly with latitude. No such simple discussion according to climatic subdivisions is possible as in the case of the tropics. Forests are found on the rainy west coasts and also in the interiors. Agriculture is practised where the forest has been cleared, and also on the steppes and even in the deserts, wherever irrigation is possible. These variations in climate from east to west and north to south across a continent, are such as to necessitate great differences in the season and methods of agriculture, and in the crops that are grown.

In the sub-tropical belts, favoured as they are in many ways as to climate, man fights against frost in California; protects his crops by walls or hedges

against high winds, as in the Azores, in Malta, and in southern France; manufactures artificial ice in Palestine; retards the ripening of his fruit under the spring sun by screening it. The latter is an interesting phase of man's effort to make the most of his climate, regulating it so far as may be possible. In parts of Italy it is customary to cover the lemons with screens of cloth or rushes, so that they may not ripen until the summer demand is at its height in England and America, and prices are good. The equable climate of the Pacific coast of the United States makes it possible to keep farm animals outdoors most, or even all, of the year, thus saving the expense of barns and stables necessary in more rigorous climates. In summer on this coast, advantage is taken of the dry season to leave wheat out in sacks, sometimes for weeks at a time, without much fear of damage by rain. This is a great convenience for the farmer. Raisins are usually dried outdoors, although some of the larger growers are now introducing drying houses. The damage done by one rain is so great when raisins are partially dry, that the field labourers at such critical times, when rain is forecasted, insist on being paid extra high wages to bring in the fruit. The kind of agricultural machinery depends largely upon conditions of climate and crops. The combined harvester and thresher used in California could not be successfully employed under other conditions of dryness and ripeness of the grain. The use of this machine is much restricted farther north, in Oregon

and Washington. It may here be noted, in passing, that in Norway agricultural machinery has been well received on account of the shortness of the summer and the need of accomplishing outdoor work quickly. Cereals are a winter crop in the regions of winter rains, and many fruits can be very successfully grown, such as lemons, figs, olives, oranges, etc. The sub-tropical vine-growing districts of Italy, Spain, southern France, California, southern Australia, and Cape Colony are natural centres for the wine industry.

The great cereal lands of the world are found in the continental interiors, in the regions of summer rains, where the precipitation is sufficient. Roughly, between latitudes 40° and 52°, other conditions being favourable, we find the principal wheat belt; but wheat is cultivated much farther north, for example in Asia, and also farther south than the above limits. Barley grows over a much wider belt, both poleward and equatorward; oats grow north of wheat, and corn grows south of it. In the higher latitudes, with shorter summers, it is more and more difficult for cereals to ripen. All over the cleared farm-lands and cultivated steppes of the temperate zone, droughts, or excessive rains, or frosts, or other harmful conditions are always to be feared. On the whole, the struggle against adverse conditions of climate, and weather, and soil, is so hard that it constantly demands man's best energies, his best methods, his best implements.

Climate has, in a large way, set apart certain great

areas where agriculture may be best carried on. Similarly, it has determined that one area shall be adapted for grazing and another for forests. Forests will always grow chiefly in the rainier regions, because, although trees can be made to grow, by careful selection and proper care, over a good deal of steppe country, they will always grow better, and faster, and more cheaply, where the rainfall is heavier. A map of the products of any country, in crops, or cattle, or forests, will show, when compared with a rainfall map, the broad, general relations which are here referred to. There is, it may be noted, often an intimate connection between a product of one sort and one of another sort, as, for example, in the case of hogs in the United States, which are raised in largest numbers in the region which produces the most corn, on which the hogs are fed. The climatic control of occupations is beautifully illustrated in Chile. In the rainy south, the forests, with lumbering and fishing; in the arid north, the deserts, which would be uninhabited were it not for the nitrate and other mineral deposits which have given the region an extraordinary value; in the central portion, with a climate neither too wet nor too dry for agriculture, we have the great farming, cereal, and stock-raising districts.

The Deserts. In the continental interiors, where the distance from the ocean is great and the enclosure by surrounding mountains is effective in intercepting the moisture brought by the winds, grass-land is

replaced by sparser and sparser vegetation; steppe merges into desert; population decreases more and more. Such arid regions are found in the deserts of south-eastern California, Arizona, and New Mexico; in northern Mexico; in the interior of the great overgrown continent of Asia. These deserts are the extreme product of continental climate. With moderate or cold winters and hot summers, the life of man in them is controlled in much the same way as in the deserts of the tropics.

No more striking illustration of this control over the primitive desert-dwellers of the temperate zone has been given than in the study made by McGee of the Papago Indian tribes of southern Arizona. "The Papago prefers to live where other people famish; he is able to do so by reason of his remarkable adjustment of his habits, his food and raiment, his industries, his social organisation, to a peculiar assemblage of conditions." These people can go long without food and water; in emergencies they secure water from the barrel cactus (*biznaga*) [1] : they chase rainstorms for miles across the desert, and plant wherever water or damp soil is found; their houses, built of mesquite saplings, protected against the ravages of cattle by thorns, or of adobe, are located near damp soil, or a water supply. The Papago's life is nomadic for much of the year because he migrates in search of the means of subsistence, of which, as McGee puts it,

[1] A good illustration may be found in Pl. xviii of the "Desert Botanical Laboratory of the Carnegie Institution," 1903.

"the first, and the second, and the third are water, *water*, WATER, to alleviate his own thirst in the sun-parched deserts, water to sustain his horses and burros and kine, water to vivify the plants of which man and his creatures eat." The seasons of planting and of harvest depend on storms, come when these may; when the local water-supply fails, water is carried long distances on burros, or on the head; the springs are protected by a corral or stockade made of cactus, and even of the dried carcasses of bulls killed in the battle for water; only the simplest arts of pottery-making are practised. All this shows a climatic control of which no better illustration can be found anywhere in the world. The thick adobe walls of the Indian dwellings of the south-western United States in general are well adapted for keeping the inside temperature equable, in spite of the large diurnal ranges outside. The Pueblo Indians show the influence of climate in their use of stone, and in the absence of wood in their buildings and utensils. Heat and cold split the rocks of their mesas and furnish material for building. The reckoning of a man's wealth according to the number of horses in his possession; the open and easily-transported huts of the Navahoes, which furnish sufficient protection against the heat and the wind of the hotter months, with more permanent winter houses of adobe, better fitted as a protection against the severe weather of the colder season; the rain-dances and rain-gods of the south-western United States,—all this is but a repetition of

what is found among the native tribes of the hot tropical desert. It has been well said by one writer that "the whole religion of the south-west may be summed up in a single phrase—a prayer for rain."

In the arid interior of Asia we see the same nomadic life, the same difficulty of travel, the same semi-pastoral, semi-industrial population along the borders or in the oases of the desert, as in the tropics. But in the temperate zone deserts there comes always the greater need of protection against more severe cold. It has been believed by many writers that a progressive desiccation in central Asia drove the inhabitants out onto the lowlands, and was followed by the Asiatic invasion of Europe; but there are not wanting those who do not believe such desiccation proved, and who doubt, as H. J. Mackinder has said, whether these changes, even if proved, have "in historical times vitally altered the human environment."

In time, civilised man will make use of every available drop of water which is supplied in these arid regions, whether by streams, or in the form of rain, or from underground, and the irrigated desert will develop in man those qualities of coöperation which have been conspicuous in the irrigated communities of Peru, among the Indians of the south-western United States, in Africa and in Asia, in Utah and in California. Where every drop of water has a money value, there results a unification of interests in the common water supply which is as striking as it is

interesting. But there is a limit to the population whose needs can be supplied in these deserts, even when every available water supply is drawn upon; and the temperate deserts, like those of the tropics, must always remain sparsely populated, as a whole, with their inhabitants collected here and there around oases, or in the larger, modern, irrigated areas. The immense public irrigation works recently completed, or now being carried out by the United States government, furnish striking illustrations of the effective use which civilised man now makes of water in an arid region, while the Mormon irrigation, practised in Utah, still remains a model of what can be accomplished by individuals working in harmony.

A typical desert industry is the harvesting of salt, as from Great Salt Lake in Utah, at Salton in the California desert, in Turkestan, Patagonia, and China. In the last-named country salt was formerly used as money, the salt industry being a government monopoly, protected by a prohibition of the importation of foreign salt. In Chinese Turkestan blocks of rock salt are sometimes used in building walls, and huts built of rock salt have also been reported. The difficulty of securing water in the temperate deserts is often serious. Baku is to-day supplied in part with water obtained by distilling the brackish waters of the Caspian Sea.

Railroad construction and operation in the temperate deserts, *e. g.*, in Arizona and south-eastern California, or on the new trans-Caspian railroad in

Asia, and on the projected trans-Australian railroad, have to contend with difficulties similar to those in the tropical deserts, to which reference has already been made. A curious effect of sand-blasting is noted from the California desert, where the telegraph poles along the railroad are so worn near their bases by the blowing sand that they have to be protected by piles of stones. The southern trans-continental railroads of the United States, which traverse the hottest and dustiest part of the interior desert, lose much travel in summer because passengers prefer the more northerly, cooler, and less dusty journey.

Mountains. The mountains of the temperate zones are often forest-covered on their upper slopes, with pasture lands farther down, and below these, the lower slopes are used for agriculture. The variety of occupations within a restricted area is thus considerable, *e. g.*, lumbering, forest industries, and hunting above; farming and fruit-growing below. Mountains which rise from steppes or deserts have the character of oases, or islands. The general conditions of climate and of life on mountains are so different from those on lowlands that it is not surprising to note the differences, often observed, between mountain and lowland peoples. The decreasing mean temperature, the inaccessibility, the smaller amount of land available for profitable use (except in the case of mines), and the decrease in plant and animal life for food, suffice to set a limit of height to the habitability of these mountains by man. Human settlements, as

a whole, therefore decrease in number and importance with increasing altitude, except where mineral wealth or forests are an attraction.

The successive vertical zones or belts of vegetation vary much in altitude above sea-level, according to the slope on which the plants grow, the warmer southern slopes (in the northern hemisphere) giving vegetation more favourable conditions at a greater altitude than the northern. A similar effect of favourable exposure is commonly seen in the distribution of population in mountainous districts. Human settlements are usually found at greater elevations on the sunnier slopes, where the conditions for agriculture and for grazing are most favourable, but temporary lumbering or mining operations may locally induce higher settlements on the shady slopes, and more favourable rainfall on the latter may also bring about a departure from the general rule. The average upper limit of settlements in the Alps coincides fairly well with the upper limit of grain. It is reported that in the Oetz Valley, in the Alps, considerably more than 75 per cent. of the population live on the sunny side of the valley. Lugeon's study of the principal valley of the canton of Valais, between Martigny and the Rhone glacier, has brought out similar interesting facts. In a certain part of this district, the villages, with but one or two exceptions, are on the sunny side. In fact, a certain distinction of classes results from this difference. There is developed an aristocracy of the sun, so to speak. The

people on the sunny side are, on the whole, more prosperous and better educated, and look with some contempt upon the people on the shady side. The marked avoidance of the lower parts of valleys in the Alps, and in other temperate mountain regions, and the building of houses on the mountain slopes or the hill-tops, depend upon the frequent occurrence of inversions of temperature. Löwl has pointed out that in parts of the Alps, terraces, fan-cones, and other topographic forms elevated somewhat above the valley floors, are thus sought out as locations for houses.

The value of land is obviously determined largely by its position with reference to slope, exposure, and liability to frost occurrence. Southern slopes (in the northern hemisphere) are usually more desirable as well as more expensive, and many examples might be given of the difference in value of land which is more exposed to frost and of that which is less exposed. California furnishes many excellent examples. A grain ranch lying in a frosty pocket may there be next to land which is practically frost-free. The latter is worth two hundred or more times as much per acre when well established in oranges. The kind of crop which can be grown, and hence the financial return, also depends largely upon exposure to sunshine and frost, protection against destructive winds, and the like, as well as upon soil.

It is a characteristic habit in many parts of the temperate zones to drive cattle up onto the higher

slopes of the mountains for pasturage in the summer months, whereas, on the approach of the winter, they are brought back to the permanent settlements below. Examples are found, among other places, in Switzerland, where the cattle and goats, with their herders and shepherds, spend the summer far up on the alp; in Sweden and Norway; in south-eastern France; on the Balkan peninsula; among certain Indian tribes and also on some of the great cattle ranches of the United States; in much of the plateau country of Asia, as on the Pamir, and in parts of Armenia, the Thian Shan, and the central Himalayas; in northern Africa, and in the Urals. The modern development of summer resorts in mountains is but another manifestation of this seasonal control of migrations by the climatic conditions resulting from the presence of mountains. Special cases of a peculiar kind are found in the Sary-Tur and Thian Shan mountains, among the Boginzes and the Kirghiz, who in winter drive their horses and herds up above the level of the winter clouds and snows to the upper pastures, which are well watered by the summer rains, and furnish abundant grass for fodder. Again, in Sistan, Ellsworth Huntington reports an occasional migration down from the relatively cool mountains during a dry season, and across the desert to the lake waters beyond. But these are exceptions to the general rule of upward migrations in summer.

The forests above the grass zone are frequently the last resort of wild animals which have retreated

from the lower slopes, and hunting expeditions in search of this game are often made.

Mountain peoples have special conditions to meet. Their dwellings are usually better built and furnish better protection than is the case on the lowlands. In some cases the people live almost or quite underground, in order to secure the maximum protection against cold, or heat, or high winds. In Kashmir some of the natives carry about, under their loose clothing, earthenware pots filled with live coals, to keep them warm. Severe winters on mountains, with little or no possibility of doing outdoor work, promote home industries. Foehn or chinook winds locally favour the raising of special crops or fruits; melt the snow rapidly, so that cattle may find sustenance through the winter; or necessitate strict regulations against fires, as in parts of Switzerland. The bora interferes with shipping along the eastern shore of the Adriatic. Mountain and valley winds sometimes locally attain such violence as to make travel or habitability difficult or impossible.

A peculiar custom which prevails among certain native tribes of the Himalayas, and which is an interesting result of climate, has been reported by Ellsworth Huntington (in manuscript). Certain Kashmiris, who live in the Himalayas between Kashmir and Ladakh, at an altitude of about 10,500 feet, spread earth on the snow in order to make the snow melt more quickly.

"Those whom I saw," reports Huntington, "were Kash-

miris who had come to the country within a generation or two, and had learned the practice from the long-settled Ladakhi or Tibetan inhabitants. The snow, April 11, 1905, was unusually deep, about 10 feet, and was not expected to disappear for nearly two months, some two weeks later than usual. In the drier region of Ladakh, nearly to the east, the practice is followed by people living as high as 14,000 feet. Sometimes a snowstorm covers the layer of soil on the old snow, and new soil has to be gathered and spread."

Travel and transportation meet with many obstacles in mountains, apart from the natural difficulties which come from steepness of slope and from forest cover. In all latitudes where snow falls in winter, obstruction by snow-blockades is a serious matter, and the question whether it is better to tunnel, or to build above the ground and keep the tracks clear by means of ploughs and snow-sheds, is an important one for the engineers to settle. The northern transcontinental railroads in North America, where they pass over the western mountain ranges, are protected for long distances at critical points by snow-sheds. These, being of wood, are apt to take fire, and fire watches and fire apparatus are provided for such emergencies. Below the latitudes where snow falls in considerable quantities, sheds are not needed. Some railroads in mountains are abandoned altogether in winter. Floods and washouts, landslides and avalanches, are additional handicaps. The famous Uspallata Pass, between Chile and Argentina, is not used by travellers in winter, on account of the

snow. Traffic then goes by steamer, by way of the Strait of Magellan. Fierce, cold winds, and the altitude, have been effective barriers in keeping Tibet so long isolated, and will remain effective barriers in the way of any movement of troops across the Tibetan plateau.

Climate and Weather: Some Mental Effects. The frequent and sudden weather changes of the temperate zones affect man in many ways, as do the larger seasonal changes. The relations between weather and conduct have frequently been investigated. Professor E. G. Dexter has made an extended empirical study of the effects of the weather in relation to deaths, suicides, the number of errors made in banks, and misdemeanours generally. It appears, as one of the most interesting general conclusions, that physically exhilarating weather conditions are accompanied by an abnormal prevalence of excesses in deportment, while deaths, suicides, and errors in banks show a decrease. So many indirect effects come into play in these conditions that care must be taken not to draw too hasty conclusions. Thus H. H. Clayton has pointed out that errors in banks may be more likely on cloudy days because of the greater difficulty in seeing figures, and also that fine weather tempts people out of doors and thus brings them into contact with others, giving opportunities for crime. Light wind movement seems to be accompanied by fewer misdemeanours in schools; low relative humidity by a larger percentage of misdemeanours; great cold

by more suicides, and so on. Bertillon has collected data on suicides and seasons in France, and Leffingwell has investigated illegitimacy and the influence of seasons on conduct in Great Britain.

The difference in the effects of a bright, crisp day, when work is well and quickly done, and of a dull, depressing, and enervating day is well known. A dismal day is a *dies mali.* Strong cyclonic winds, blowing polewards from lower latitudes, are characteristic of the temperate zones, and are proverbially disagreeable and irritating, in strong contrast with the cooler winds from higher latitudes. The sirocco in Italy; the solano in Spain; the norte in Argentina, for example, are such winds. The sirocco has been described as "not fatal to human life," but "deadly to human temper." In Spain there is a proverb, "Ask no favour during the solano." The nervous effects of the dry foehn and chinook are well known. The zonda of the Argentine is reported as not infrequently making people temporarily insane, and leading to suicide. Many other mental effects of the weather might be noted.

Climate, Weather, and Military Operations. Historical consequences of great importance have followed from special conditions of climate or weather. Maguire's *Outlines of Military Geography* (Cambridge, 1899) contains a chapter on the influence of climate on military operations, but this subject has hitherto received little attention. More recently, Bentley, in a presidential address before the Royal

Meteorological Society, London, considered the matter. A few illustrations only can here be given.

The fleet of Xerxes was lost in a storm on the coast of Greece. In 54 B.C., owing to a preceding drought and scanty harvest, Cæsar was obliged to scatter his army in separate winter quarters, and in this situation one of these isolated bodies of Romans was attacked and destroyed. The consequences came near being very disastrous for Cæsar. A storm destroyed the Spanish Armada. The French Revolution was precipitated by a severe winter. Napoleon was defeated in 1796, owing to the ground being too heavy for the movement of the French artillery. In 1796, also, Gen. Hoche's fleet, sailing for Ireland, was scattered by a storm. The terrible winter retreat of the French from Moscow furnished a vivid illustration of the strength of the two invincible Russian generals, January and February (to use a Russian expression). The battle of Waterloo was postponed on account of a heavy rainfall. The siege of Sebastopol furnished another illustration of the suffering which a severe winter may produce. The "Boxer" outbreak in China, in 1900, was precipitated by a scarcity of rain in the preceding autumn, bringing on destitution and famine, and driving the people to pillage and robbery. During the fighting around Tientsin, early in July, the situation of the allied troops was very critical when a torrential rainfall compelled the Chinese to retire. During the Boer

war there were many instances of weather controls over military operations. On January 9, 1900, a heavy rain checked the fighting near Ladysmith, and cloudy weather often prevented the use of the heliograph in communicating with Ladysmith. During the recent British campaign in Tibet, great difficulty was experienced at the higher altitudes, owing to the hardening of the oil in the guns on account of the cold, and the low boiling point made it difficult to cook food properly in the absence of cooking utensils adapted for use at low pressures. In the Russo-Japanese war, the cold and heat and rain made themselves felt as powerful factors in the campaign.

The effect of even one rain may be far-reaching. It has been said that a shower of rain acts like a wet blanket on a mob. Numerous recent illustrations of the truth of this statement are available. A rain in Paris on the day of the Dreyfus verdict, in September, 1899, doubtless helped to prevent, if it did not actually prevent, an outbreak. During a great strike in Moscow at the end of January, 1905, a snowstorm greatly helped the authorities in keeping the people off the streets. Again, on April 6, 1906, at St. Petersburg, a steady downpour of rain all day prevented an open-air meeting which would doubtless have led to conflict with the military.

Railroads. Railroads have reached their greatest development in the continental climates of the temperate zones, and the influence of these climates upon the construction and operation of these roads is far-

reaching, varied, and of the greatest economic importance. Transportation by rail is necessarily closely affected by weather conditions, for trains have no protection against snow, or wind, or heat. The extremes of heat and cold have a racking effect upon all iron and steel work, and careful allowance has to be made for this factor. Floods wash away bridges, tracks, and ballast. In the Mississippi basin of the United States, floods in 1903 cost the Sante Fé Railroad alone $1,000,000. Stormy weather means bad country roads, and this may prevent the transportation of farm products to the railroads, and thus result in irregularity in the supply of freight. It is believed that were freight delivered regularly, the railroads would find it possible to use less rolling stock, with better returns.

Many of the most obvious climatic handicaps are seen in the more northern latitudes of the north temperate zone, where the winter brings snow and ice. The trans-Siberian Railway was constructed with great difficulty because of frozen soil, spring thaws, and upheaved tracks. Across the rivers and across Lake Baikal, rails were laid on the ice during construction times. Later, the trains were carried across the lake in winter on ice-breaking ferryboats. The houses for the labourers were also built on the ice. Work was greatly interrupted during the winter. On the Great Lakes of North America, temporary rails are laid on the ice during the ice-cutting season. The new trans-Canadian railway lines will traverse

a region of severe cold in winter, but generally of moderate snowfall, and although situated far to the north, they will draw upon a splendid wheat crop, favoured by the warmth and well-distributed rains of summer. The snow-blockades on the northern railroads of America led to the invention and use of the ingenious and effective rotary snow-plough; to the planting of trees along the right of way to serve as snow-breaks, and to the construction of snow-fences. In Siberia, the snow itself is occasionally piled up in heaps by means of ploughs or shovels, and is thus made to serve as a windbreak. The campaign of a modern electric street railway system, in an American city, against the winter's snow, is carefully planned in the preceding summer, and every detail is worked out beforehand. A mild, open winter in latitudes where winter snowfall is an important factor in railroad operation, means a saving of money, time, and labour, which results in increased earnings and even in larger dividends. The motive power which is otherwise employed in fighting snow is then earning money for the company.

In the warmer latitudes and drier seasons the blowing sand and dust are disagreeable, and even delay transportation at times. High temperatures and heavy rainfall hasten the decay of railroad ties. The growth of weeds on the right of way of earth-ballasted roads is a considerable difficulty in many parts of the temperate zones, as well as in the tropics. In the United States, the Union Pacific Railroad has used

a gasoline weed-burner, which scorches off the vegetation, and the salt water of Great Salt Lake, sprinkled over the road-bed, has also been found to serve well as a weed-destroyer.

The state of the weather sometimes fixes the load of an engine, as in the case of freight trains running west from Pittsburg, Pennsylvania. According to the weather forecast of favourable, reasonably good, bad, and very bad weather, the load of a freight engine varies from 1750 tons to 1225 tons. The business of railroads depends largely upon the season, but the time at which these roads are generally the most useful, and also the most overburdened, is after harvest-time. Then, in the great wheat regions of North America, the immense crops can with difficulty be handled and stored, and the need of money to "move the crops" not infrequently leads to financial readjustment and stringency in the money market.

Transportation by Water. The oceans at the equatorward margins of the temperate zones have the light, variable winds and calms of the horse latitude belts, with the seasonal change from trades to westerlies, and back again. From the Mediterranean, a fairly calm sea with few storms, came many of the early navigators and explorers, doubtless tempted to sea by the regularity and steadiness of their winds and by the clearness of the air which, before the days of lighthouse, compass, and telescope, aided navigation by making it easy to see distant landmarks. In the higher latitudes, the prevailing westerlies, blowing

with moderate to high velocity and frequently disturbed by storms, especially in winter, generally favour voyages to the eastward, but are head winds for vessels sailing westward. The voyage from Europe to North America is not an easy one for sailing ships, for, in addition to the head winds, there is also the danger of ice and of fog on the Banks of Newfoundland. The sailing route from Europe to North America by way of the north-east trade, and back, more directly, in the westerlies, makes effective use of these two great wind systems. To keep clear of ice and fog, the North Atlantic steamer routes at certain seasons keep farther to the south, with the disadvantage of lengthening the distance travelled. Ocean currents, which are meteorological phenomena because wind-driven, are important factors in controlling the location of sailing routes. The voyage around Cape Horn to the westward, in the teeth of boisterous westerly gales, is much dreaded by seamen. Outward-bound vessels from England to Australia find it convenient to sail by the Cape of Good Hope, while on the homeward voyage they can round Cape Horn to the eastward. By so doing they have a good chance of fair winds all the way. The most favourable weather condition for passing Cape Horn to the westward is the presence, during the period necessary for rounding the Horn and for crossing latitude 50° S. in the Pacific, of a centre of low pressure in the immediate vicinity of the Cape, and not too far to the southward. This pressure dis-

tribution gives north-east, east, and south-east winds in succession in the case of a west-bound vessel which passes the centre to the southward. The cyclones of the westerlies are always more or less of a hindrance and danger to shipping. Storm winds have, it is true, accidentally led to the discovery of new lands, but stormy seas do not tempt man to sail upon them. Protected harbours are naturally sought; unprotected harbours are provided with breakwaters and docks; low-lying coasts, like those of Germany and Holland, are subject to damage and flooding, and even loss of life, by storm waves and high tides. Even on the borders of the temperate zones, in the sub-tropical belts, the winter cyclones of the westerlies occasionally give rise to gales dangerous to shipping, as on the coast of California and of Chile. When a strong norte blows at Valparaiso, as it sometimes does in the winter season, the vessels at anchor in the harbour are obliged to steam or to be towed out into the open ocean, in order to avoid being blown ashore. The vessels in this harbour are anchored at both bow and stern, always facing the north.

The freezing of harbours at the termini of the northern railroads is a serious handicap in many countries. Ice-breakers are used by Russia at Vladivostock; and at Hango, Cronstadt, St. Petersburg, and other ports on the Baltic. Germany's northern ports suffer more or less from the inconvenience of ice in winter. The closing and opening to navigation of the grain ports is a matter of the greatest importance in the world's

grain trade. Canada is much handicapped by the freezing of the St. Lawrence River. The trans-Atlantic steamers change their sailings in winter to ports that are accessible the year around. It has been proposed to use an ice-breaker to keep the St. Lawrence open longer in the fall, and to break up the ice earlier in the spring. The projected route from Canada to Europe by way of Hudson's Bay is obviously greatly handicapped, if not rendered wholly impracticable, by the winter ice. On the frozen Gulf of Finland a considerable population of fishermen live on the ice for several months; building houses for themselves and abandoning for a time their usual occupation of farming. On the frozen Neva, at St. Petersburg, street traffic goes on as on dry land; roads are made over the ice; the streets are lighted; cars are run and fairs are held.

Various Effects of the Weather. Effects of varying conditions of seasons and weather are observable on all sides. The march of the seasons brings a succession of occupations. Thus farming, building, painting, and outdoor work generally, are prominent occupations in the warmer months in much of the temperate zones. Lumbering, ice-cutting, and snow-shovelling are distinctly occupations of the colder months in the higher temperate latitudes in the United States. In North America the harvesting of the cereal crops calls for thousands of harvest hands every summer, many of whom begin work in the south and gradually work north into Canada, as the crop

comes later and later in the season with increasing latitude. It is worth noting, in passing, that the wheat harvest in Argentina usually begins late in November in the north, and progresses southward until February; in India, the harvest begins late in February in the south and progresses northward until early in May. The Indian and Argentine wheat thus come to market in what is known as the "dead season" in the other wheat countries, and therefore have an important effect on prices.

Rainfall, insufficient in quantity or poorly distributed, leads to a failure of the crops, and one or more years of crop failure may bring on a general financial depression. Even political overturns, as has been shown by Clayton for the United States, have been brought about by deficient rainfall resulting in short crops, and a similar occurrence has not been unknown in England. Political consequences following crop failure have been traced to the occurrence of destructive hot winds in Kansas in 1890 and 1891, which gave the Populist Party national importance. The financial value of one rain, at a critical time of drought, can sometimes be approximately estimated. In Kansas and Nebraska, in 1900, the value of one rain, lasting twenty-four hours, in saving the corn crop was put at over $80,000,000. In Australia, the wheat crop, as has been shown by Wills, is so closely related to rainfall that the ratio of wheat in bushels per acre and the annual rainfall in inches has been made out to be a remarkably

definite one. Similarly, the number of sheep per square mile in Australia and in Argentina depends very closely upon the rainfall, as has also been shown by Wills. Unseasonable weather, at any time of year, disturbs trade, which is very closely adjusted to the normal weather conditions that may reasonably be expected at any given time. Strikes have come to an end because of the approach of cold weather, and the prospects of suffering among the strikers; and strikes have continued during great heat because of the desire of the men to remain idle at such times. Certain atmospheric conditions seem to be more favourable than others to spontaneous combustion. A dense London fog causes a heavy money loss in the extra expense for gas and electric light, and in the delay and damage to shipping. It has been estimated that the cost of the gas burned during one day of an ordinary London fog approximates $15,000. In New York city, the coming of a summer afternoon thunder storm is reported by watchmen to the electric-light power-houses, where the dynamos are set going at full speed in order to supply the sudden demand for extra light. In England, a good deal of business is done by insurance companies in indemnifying cricket clubs against loss in case an important game happens to be interfered with by rain. So many claims have arisen for the insurance money that it has become customary in such cases to stipulate what amount of rain shall fall in order that the claim shall be paid. Insurance against damage by tornadoes,

lightning, hail, etc., illustrates the efforts of man to guard against loss due to hostile features of his weather and climate. The danger from tornadoes on the western plains and prairies of the United States has led to the building of underground "dug-outs," or tornado cellars, which are somewhat akin to the underground winter dwellings of some of the natives tribes of northern Siberia, built as a protection against winter storms. Such illustrations might be multiplied indefinitely.

CHAPTER X

THE LIFE OF MAN IN THE POLAR ZONES

General: A Minimum of Life—Culture—Subdivisions of the Arctic Zone—Characteristics of the Tundra—The Reindeer—Population and Occupations—Dwellings—Food and Clothing—Iceland—The Polar Ice Cap: The Eskimo—Dwellings—Food and Clothing—Travel and Transportation—Occupations and Arts—Customs—Deserts of Sand and Deserts of Snow.

General: A Minimum of Life. The conditions of life are necessarily very specialised under the peculiar climatic features which are met with in the polar zones. A "monotony of cold" replaces the "monotony of heat" of the tropics, and instead of the spur of the temperate zone seasons there is the depressing, long, polar night. There is a minimum of life, but life is more abundant in the north polar than the south polar zone, and our knowledge is confined chiefly to the former area. Plants are few and lowly. In the farther north, only a few mosses and lichens are found. Land animals which depend upon plant food must therefore likewise be few in number. Farming and cattle-raising cease. The reindeer, which manages to find sufficient food in the lowly Arctic vegetation, is the mainstay of many of the

Arctic natives. But the reindeer must wander far and wide in search of their moss. And many reindeer are needed to provide sustenance for one man. Population is small and scattered. There are no permanent settlements at all within the Antarctic circle. And the few scattering islands in the immediately surrounding, vast ocean area of the south temperate zone are likewise uninhabited, except temporarily by shipwrecked seamen or, lately, by members of scientific parties. In the Arctic area human settlements are fairly well scattered over a considerable range near the margins of the zone, but with increasing latitude man is more and more rarely seen, and finally he disappears entirely. There will never be permanent human settlements at the poles. Life is hard; a constant struggle for existence. Man seeks his food by the chase on land, but chiefly in the sea. Hardly a tenth of Greenland's population could live there without food from the sea. It has been well said that with every degree of higher latitude man is more forced to obtain his food supply from the sea. He lives along, or near, the sea coast. The interior lands, away from the sea, are deserted. Gales, and snow, and cold, cause many deaths on land, and also at sea, especially during fishing expeditions. It has been estimated that about one twenty-fifth of the population of Iceland perishes through being lost in snowstorms, by freezing, or by drowning. In the Faroe Islands about 8%, and in Greenland 7% of the deaths have been reported as due to drowning

accidents of one sort or another. Rink has reported of Greenland that most of the deaths occur at seasons of most profitable sealing operations. Such difficult conditions of securing food make famine a likely occurrence. If a successful hunting or sealing expedition follows a time of famine, the natives are wont to indulge in the most revolting gorges. The polar limit of permanent human settlements is believed by Bessels to be fixed, not by the decreasing temperature, but by the increase in the length of the night, which shortens the time during which man can lay up food by hunting and fishing, to last him through the polar night. The chase after land animals has helped to drive the latter farther and farther north.

Culture. Under such adverse conditions it is not hard to see that progress towards a higher culture is not a reasonable expectation. There is no time in which man may seek to develop and satisfy his higher needs. Much truth is contained in Guyot's somewhat picturesque statement: "The man of the polar regions is the beggar overwhelmed with suffering, who, too happy if he but gain his daily bread, has no leisure to think of anything more exalted." Thus the inhabitants of the north polar zone have not played an important rôle in the history of human progress. A sparse population, not far advanced in culture or in social relations, is inevitable under polar conditions of climate. Yet the courage of the Eskimo in braving a raging sea in his *kayak,* or in facing a polar

bear; the docility, industry, good nature, and other attractive qualities of these people, which have been described by more than one Arctic explorer; the intelligence and the patience with which they have overcome the disadvantages of their environment; the contributions made by Iceland to the world's literature—these and other similar considerations make us pause before passing too hasty a judgment. Polar cold has not produced a distinct type of polar man, but the general effect of the polar climate in eliminating cattle-raising and agriculture—except to a very limited extent, and in a few favoured localities—from the list of human occupations; in turning man to the sea for his food; in magnifying the importance of animal products, especially bones, in the production of domestic utensils and weapons, is more or less familiar among all Arctic tribes. There is no steady, profitable occupation in which large numbers of men may be regularly employed at good wages. Broad, general analogies have been traced between the northern Eskimos and the Fuegians of far southern South America.

Subdivisions of the Arctic Zone. For the purpose of this consideration the north polar zone may conveniently be subdivided into (1) the lowlands of the tundra, where the summer sun melts off the snow and thaws out the upper few inches, or possibly few feet, of the frozen ground, and (2) the permanently ice- and snow-covered higher land, where the heat of the summer does not remove the icy cover, and where

man, so far as he inhabits those districts at all, must live along the margins of the ice-cap, near the sea. In whichever portion of the Arctic man is found, his general mode of life, his occupations, his dwellings, food, clothing, arts, and so on, are rigidly controlled by climate.

Characteristics of the Tundra. The low-lying frozen desert along the shores of the Arctic Ocean is known as the tundra. "Barren Lands" is the name by which it goes in Canada. Through belts of lowly, scattering trees, these lowlands gradually merge on the south into the northernmost forests of the temperate zone. To the north are eternal snow and ice. Over the treeless tundra the soil is permanently frozen to a great depth, but the upper part of the surface thaws out sufficiently during the summer to produce a great plain, more or less swampy, which may become dry in places in midsummer. Scattered clumps of trees, chiefly along the water-courses, relieve the monotony of the dead-level here and there, and during the summer the tundra is covered for a few weeks with lowly lichens, mosses, and ferns, or even with the green leaves of stunted berry-bushes, whose roots are all near the surface. At this season, also, brilliant flowers, insects, and birds give life and charm to the scene. With their polar characteristic of an extraordinarily rapid growth, under the summer sun, the plants of the tundra awaken as if by magic. The summer is in striking contrast with the winter, when these great plains are frozen

solid, rivers and all, under a broad sheet of snow. Journeys by dog or reindeer sledge, or on skis, can be made in any direction, regardless of the presence of water or land beneath the snows, the routes to be followed being accurately indicated by means of landmarks. Thus in the Yukon country of Alaska, as long as the rivers remain frozen, dog-sledges are used in the interior to carry the mails and other freight. This is much more expensive than the summer transportation by boat. When the snow is in good condition, the natives can travel at the rate of fourteen or fifteen miles an hour on skis. In spring and early summer, when the upper portions of northward flowing rivers melt, while the lower portions are still frozen, floods are frequent over the lowlands. In the transition season, when the rivers are not frozen and the ground is not snow-covered, travel is usually difficult or impossible. In the month of October, in northern Russia, for example, the government mail service is discontinued, labour contracts are off, and the keepers of stages are freed from their usual obligations. The fact that her northern ports are icebound in winter is a serious handicap to Russia. This was one of the principal reasons for her desire to secure an ice-free port on the Pacific, Vladivostock, the original terminus of the trans-Siberian Railroad, being also ice-bound in winter. This led to the acquisition of Port Arthur, and eventually to the war with Japan. An open port would be an immense gain for Russia, which has been much handicapped

in training her sailors by the freezing of the Baltic harbours in winter.

The Reindeer. The reindeer in Eurasia and the caribou in North America are the most important animals of the tundra. They feed on lichens and mosses, or stunted shrubs. The reindeer is wonderfully adapted to the natural conditions under which it lives. With wide hoofs, well-fitted for travel over the snow, it moves very swiftly. Able to endure great cold, it scrapes through the snow in winter to find the reindeer moss on which it feeds. It migrates northward in summer and southward to the forests in winter, in search of food. The reindeer has been partly trained as a domestic animal by the natives of the tundra. To them, the reindeer is of the utmost importance: a man's wealth is rated according to the number of these animals in his possession, and their loss, by reason of famine or disease, usually means that the owners are reduced to poverty. The reindeer supplies milk and flesh for food; it is an excellent draught animal; its skin, and sinews, and bones furnish material for clothing, tents, and utensils and weapons of all sorts.

Population and Occupation. The scattered nomadic tribes of the tundra, a semi-pastoral and semi-hunting population, wander about with their reindeer over the vast stretches of the tundra, stopping wherever the animals find food; having no settled abode; making little progress in the cultivation of the higher arts. Population is inevitably sparse, and will so re-

main. The Lapps; the Eskimos, along the borders of the Arctic Ocean; the Samoyads, Yakuts, Ostyaks, Tunguses—all have a common mode of life. Hunters and fishermen by force of circumstances, they can never become farmers. In winter, they hunt for small fur-bearing animals or for larger game along the borders of the southern forests. In summer, they fish in the rivers or along the shores, storing away food for the winter. They are always on the move. Some of the tribes live along the forest borders in the winter, for the sake of the shelter there provided. The men procure food and make the needed implements and weapons. The women prepare the food and clothing; watch the reindeer; collect berries in summer; dry the fish; and even take charge, among the Samoyads and Ostyaks, for example, of setting up and taking down the tents, in order that the men may have more time for the chase. The ill, the weak, and the aged receive little attention.

Dwellings. The inhabitants of the tundra protect themselves against the inclemencies of the weather in summer by means of portable tents made of skins or bark, supported by poles. In winter, the structure is often more substantial, having more coverings or being made of turf, or, in the case of some of the Lapps, even of snow. Where timber is scarce, far from forests, the Samoyads and Ostyaks consider their tent-poles very valuable property, and carry them along with the greatest care. The tribes who live nearer the forests do not take the trouble to

transport the tent-poles when they move. In the far north, away from the forests, driftwood is an important source of lumber supply. The furnishings are very simple and easily moved when tents are struck. Furs and skins are the principal articles of trade among the inhabitants of the tundra.

Food and Clothing. The natural food is obtained chiefly from the reindeer and other land animals and wild fowl, whose flesh is often eaten raw. Reindeer milk, fish, berries, and a little other vegetable food, are occasionally added to the monotonous and unattractive diet list, as is fresh or dried blood. Trade with the neighbouring, more highly civilised people on the south gives tea and coffee, tobacco, and other articles of food. In northern Alaska caribou, bear, salmon, rabbits, grouse, and ptarmigan make up the principal food of the natives.

The clothing of the tundra tribes shows climatic control in the character and in the simplicity of the materials used. Furs and skins are universally employed. The Samoyads, Tunguses, and others often ornament their furs with bands of brightly coloured stuffs, when these can be secured. Mittens, caps, and boots of fur are essential for protection against the winter cold. Implements of the chase and domestic utensils are ingeniously made of wood, when available, or of the skin, sinews, and bones of the reindeer. Needles and spoons are commonly made of bone; for thread, gut is used. It is worth noting that the fossil elephants found frozen in the gravelly

river banks of the Siberian tundras have, ages later, furnished ivory for the Chinese to fashion into their delicate and beautiful carvings.

Iceland. Although outside of the Arctic circle, Iceland is within the polar zone according to Supan's classification. Its climatic conditions are, however, peculiar on account of its being an island, exposed to the tempering influence of the warm Atlantic waters. Favoured as it is, the climate is unsuitable for grain, breadstuffs and other articles of food being imported. Sheep, cattle, and horses are raised, and fish, feathers, skins, horses, wool, tallow, and other local products are exported. The summer is the natural time for travel, by land or water, and for this reason, the judicial assemblies have in the past been held in that season. The natives of Iceland, although much handicapped, have played their part in the world's progress, as enterprising sailors and discoverers, and have developed a literature.

The Polar Ice-Cap: The Eskimo. The polar people *par excellence,* the Eskimos, live characteristically on the margins of the Arctic ice-cap, beyond the tundra, along the shores of the Arctic seas. The Eskimo, in common with other Arctic natives, must secure his food almost wholly from the sea. When he needs to travel to any distance for food, he moves his dwelling. He is necessarily nomadic in his habits. His existence is in many ways not unlike that of the hunting tribes of the equatorial forests.

Dwellings. The rude but substantial dome-

shaped ice or snow hut (*igloo*) of the Eskimo furnishes one of the most striking illustrations of the climatic control over human dwellings. Built low, and entered by a low passageway, the doorway may be closed with a block of ice or snow, and thus cold and drifting snow and prowling animals are kept out. The *igloos* are furnished with the simplest utensils—a "stove" or lamp to give heat and light, with blubber for fuel and oil, and dried moss for a wick; a dish for melting ice for drinking purposes, and for heating the seal or other meat. A clear sheet of ice, made air-tight by having water poured over it, not infrequently does duty as a window as effectively as a pane of glass, and is even preferred to glass. These snow huts are carefully built, as pointed out by Woeikof, not of freshly-fallen snow, but of snow well-compacted by successive storms and winds. The snow becomes dense by this means, and not by being successively melted and frozen, as in a névé. In the drier parts of Greenland, simple earth or stone houses are also used, and in the larger towns wooden houses, built of imported lumber, are the ordinary residences of the inhabitants. The snow *igloo* is the common type of the more permanent winter dwelling. In summer, when these huts may be damp with melting snow, the nomadic Eskimo travels with tents made of skins, sewed with animal sinews or strips of leather, and set up with tusks or bones. Settlements, established during wanderings in search of good hunting and fishing grounds, may fre-

quently be occupied and abandoned several times, and the ruins of abandoned settlements north of the present limits of human habitations may probably often be thus explained. Even in winter, if the food supply gives out, changes of residence are not uncommon.

Food and Clothing. The clothing of the Eskimo is made of skins of the reindeer, seal, or bear, or of birds, worn almost in their natural state. As a protection against the cold, the face is often smeared with fat. Food consists chiefly, or wholly, of heat-producing materials, such as bear or seal meat, and blubber from seal, walrus, or whale, eaten raw or barely heated through. Any surplus food is usually well preserved by the cold.

Travel and Transportation. The need of quick travel, over great distances on land, in search of food, makes the dog-sledge an indispensable possession of the Eskimo. The dog, living on animal food, can travel farther north than the reindeer, and is the typical polar draught-animal beyond the reindeer country. The dog-sledge has spread the Eskimo far and wide over the Arctic zone. Conditions are not always equally favourable for sledging. Sometimes the runners are covered with ice to make them smoother and to prevent their sinking into the snow. In Labrador, the winter storms which sweep off the loose snow and leave the surface hard and smooth are welcomed as giving the best conditions for sledging.

Occupations and Arts. Hunting and fishing,

training the dogs, and making *kayaks,* sledges, weapons, and utensils are the chief occupations of the men, while the women make the clothing and chew the skins to soften them. The Eskimo displays the greatest mechanical skill and ingenuity in fashioning all his tools and utensils. As trees do not grow in his country, wood is so scarce that every bit of it is used, small pieces even being bound together with leathern thongs to make the handles of knives and harpoons, and the like. Every piece of driftwood is a precious possession, more valuable often than iron. Driftwood plays an important part in the history and laws of Iceland, and Nansen says that the driftwood "carried down by the polar current along the east coast of Greenland and up the west coast is . . . essential to the existence of the Greenland Eskimo." Wood and iron are used instead of bone and skins. The utensils of Arctic natives show at once whether or not they have had access to supplies of driftwood. It has been well said that where driftwood is found undisturbed this is good evidence that there are no Eskimos in the vicinity. The distribution of man thus depends largely on the course taken by the driftwood. The skill of the Eskimo is well shown in his construction of the *kayak,* made of skins sewn together and stretched over a framework, a marvel of lightness, indestructibility, and portability, easily righted if overturned, which fits the boatman as if he and his boat were one. Needles and thimbles are made of bone; animal fibres are used for thread; narwhal tusks serve

as tent-pegs. The Eskimo can make or mend anything that he uses. Nothing is wasted. The Eskimos are naturally expert sailors, because of their life on the sea. In towing their catches to land, they make use of inflated bladders or skins.

Customs. The lack of water, and the cold, combine to make personal cleanliness difficult, and the people are characteristically very dirty. The winter, when the Eskimos are living in their more permanent huts, is the time for social visiting, and then they travel for miles in the family sledges to visit their friends. Marriages take place at an early age, especially among the women, and the return of the sun after the long winter has a stimulating effect on the animal passions which leads to sexual excesses of all kinds.[1]

Deserts of Sand and Deserts of Snow. The hot deserts of sand near the equator and the frozen deserts of snow near the pole are singularly alike in many ways in relation to man. Both alike repel him. Both are largely or wholly destitute of vegetation, of wood, and of water. The grey or yellow desolate waste of the sand desert is matched by the monotonous white surface of the snow desert. There are no opportunities for accumulating wealth in either. Travel is difficult in both. In one, the camel is the typical beast of burden; in the other, the reindeer and the dog are man's most useful possessions. The monotonous

[1] Dr. F. A. Cook: "Some Physiological Effects of Arctic Cold, Darkness and Light," *Med. Rec.*, June 12, 1897, pp. 833-836.

heat and glare and silence of the sand desert find their counterpart in the cold and glare and silence of the snow desert. The air is generally clear in both, except for the dust over the sand desert and the ice-needles in the air of the snow desert. In both deserts man in very limited in his food supply; in the Sahara, the date, and in Greenland, the seal, are typical staple articles of diet. The aridity in one, the cold in the other, are man's great enemies. The inhabitants of both deserts are nomadic. Settlements of some permanency are found in oases or along the edges of the sand desert where there is water; similarly, the natives of the far north live along the edges of the ice desert, where they can best find their food. The sand deserts are deserts because they are arid. The snow deserts are deserts because they are cold. Denudation of exposed rocks in both types of desert is largely due to the action of wind, for running water is seldom found. The dust of disintegration is carried away by the winds, and sand-blasting has been reported of the antarctic desert as well as of the Sahara. The polar deserts are perhaps on the whole better suited to life than the sand deserts, for the former do supply water from melted snow and ice, and over the tundra portion of the frozen desert there is an abundance of water in the rivers in summer, with moss, berries, and other vegetation, as well as animal food. Man has, however, a harder struggle to protect himself against the cold than against the heat. for he needs more clothing, and better shel-

ter, and fire. In both deserts life is isolated and primitive. The sand desert is crossed by caravans and trade routes between the more populous lands on either side, and the people of these deserts have more contact with civilisation than do most of the natives of the far north.

CHAPTER XI

CHANGES OF CLIMATE

Popular Belief in Climatic Change—Evidence of Climatic Changes Within Historic Times—What Meteorological Records Show —Why the Popular Belief in Climatic Changes is Untrustworthy—Value of Evidence Concerning Changes of Climate—Periodic Oscillations of Climate: The Sun-spot Period—Brückner's 35-Year Cycle—Climatic Cycles of Longer Period—Geological Changes in Climate—Conclusion.

Popular Belief in Climatic Change. Belief in a change in the climate of one's place of residence, within a few generations, and even within the memory of living men, is widespread. It is confined to no special region or people. It finds support among the most intelligent as well as among the uneducated. Here it may be the view that the climate is growing milder; there, that the winters are becoming more severe; here, that there is increasing aridity; there, that the rainfall is greater. Whenever a season attracts attention because of weather conditions which seem in any way unusual, this belief is strengthened. This popular impression has often found support in the facts of distribution, or the dates of flowering, or ripening, of certain cereals or fruits. It is asserted that because grapes, or corn,

or olives, for example, are now no longer grown in parts of Europe where their cultivation was once an important occupation, we must conclude that the climate has changed from a favourable to an unfavourable one.

Evidences of Climatic Changes within Historic Times. Evidence is constantly being brought forward of apparent climatic variations of greater or less amount which are now going on. Such reports, largely those of travellers or explorers in little-known regions, are usually based on fluctuations in the extent of inland lakes; on the discovery of abandoned dwelling sites, the ruins of aqueducts and irrigating canals, and the like. Thus we have accounts of a gradual desiccation which seems to have been going on over a large region in central Asia, during historical times. In eastern Turkestan the lakes have been reported as drying up, Lake Balkash falling one metre in about fifteen years, and Lake Alakul gradually becoming a salt deposit. In his work on Turkestan, Muschketoff gives numerous examples of progressive desiccation, and Rossikoff speaks of the drying up of the lakes on the northern side of the Caucasus. The same thing is reported of lakes in the Pamir. Prince Kropotkin believes that the desiccation of central Asia in the past drove the inhabitants out onto the lowlands, producing a migration of the lowland peoples and thus bringing on the invasions of Europe during the first centuries of our era. In his recent work on the basin of eastern

Persia, Transcaspia, and Turkestan, Huntington believes that, so far as it can be made out, the history of these countries indicates a gradual desiccation from early historical times down to the present day. His study of climatic changes in that region is one of the most thorough ever made, for the evidences of archaeology, of tradition, of history, and of physiography have been carefully matched and found to accord in a very striking manner. Evidence has been found of the abandonment of successive village sites as the inhabitants moved farther upstream in search of more water, and patches of dead jungle show that vegetation once flourished where aridity now renders plant growth impossible.

In northern Africa, certain ancient historical records have been taken by different writers to indicate a general decrease of rainfall during the last 3000 years or more, the remains of cities and the ruins of irrigating works pointing to a larger population and a greater water supply formerly than at present. The presence of certain animals, now no longer found there, is implied by ancient records, and from this fact also, a change of climate is inferred. In his crossing of the Sahara between Algeria and the Niger, Gautier found evidence of a former large population. A gradual desiccation of the region is, therefore, believed to have taken place, but to-day the equatorial rain-belt seems to be again advancing farther north, giving an increased rainfall. Gautier divides the history here into three periods: (1) dense population;

(2) aridity; and (3) the present change to steppe character.

Farther south, several lakes have been reported as decreasing in size, *e. g.*, Chad, Ngami, and Victoria; and wells and springs as running dry. In the Lake Chad district, Chevalier reports the discovery of vegetable and animal remains which indicate an invasion of the Sudan by a Saharan climate. Neolithic relics indicate the former presence there of prosperous communities. Again, to note another instance, it is often held that a steady decrease in rainfall has taken place over Greece, Syria, and other eastern Mediterranean lands, resulting in a gradual and inevitable deterioration and decay of their people. These examples might be multiplied, for reports of climatic changes of one kind or another are numerous from many parts of the globe.

What Meteorological Records Show. As concerns the popular impression regarding change of climate, it is clear at the start that no definite answer can be given on the basis of tradition, or of general impression, or even of the memory of the "oldest inhabitant." Human memories are very untrustworthy, and there are many reasons for their being particularly untrustworthy in matters of this kind. The only answer of real value must be based on what the instrumental records of temperature, and of rain and snowfall show. Accurate instruments, properly exposed and carefully read, do not lie; do not forget; are not prejudiced. When such instrumental records,

scattered though they are, and difficult as it is to draw general conclusions from them, are carefully examined, from the time when they were first kept, which in a few cases goes back about one hundred and fifty years, there is found no evidence of any progressive change in temperature, or in the amount of rain and snow. Apparent signs of a permanent increase or decrease in one or another element have been fairly easy to explain as due to the method of exposing the thermometer, or of setting up the rain-gauge. Little care was formerly taken in the construction and location of meteorological instruments. They were usually in cities, and as these cities grew, the temperature of the air was somewhat affected. The rain-gauges were poorly exposed on roofs or in court-yards. The building of a fence or a wall near the thermometer, or the growth of a tree over a rain-gauge, is enough, in many cases, to explain any observed change in the mean temperature or rainfall. Even when the most accurate instrumental records are available, care must be taken to interpret them correctly. Thus, if a rainfall or snowfall record of several years at some station indicates an apparent increase or decrease in the amount of precipitation, it does not necessarily follow that this means a permanent, progressive change in climate, which is to continue indefinitely. It may mean simply that there have been a few years of somewhat more precipitation, and that a period of somewhat less precipitation is to follow.

For the United States, Schott, some twenty years ago, made a careful study of all the older records of temperature and rainfall, including snow, from Maine to California, and found nothing which led to the view of a progressive change in any one direction. There was evidence of slight variations of temperature, occurring with the same characteristics and with considerable uniformity over large areas. These variations have the characteristics of irregular waves, representing slightly warmer and slightly cooler periods, but during the fluctuations the temperature differed by only a degree or two on one side or the other of the mean. Obviously, this is too slight a range to be of any general or practical interest, and in any case, these oscillations give no evidence of a continuous change toward a warmer or a cooler climate. Schott found that these waves of higher and lower temperature followed one another at intervals of about twenty-two years on the Atlantic coast. In the interior, the intervals were about seven years. The records of the closing of rivers to navigation, the Hudson, for example, show no permanent change in the dates for the last hundred years or so.

It has been well pointed out that if a list were carefully compiled of heavy snowstorms, of droughts, of floods, of severe cold, of mild winters, of heavy rains, and of other similar meteorological phenomena, for one of the early-settled sections of the United States, beginning with the date of the first white settlements and extending down to the present day, we should

have the following situation: Dividing this list into halves, each division containing an equal number of years, it would be found, speaking in general terms, that for every mild winter in the first half, there would be a mild winter in the second; for every long-continued drought in the first division, there would be a similar drought in the second; for every "old-fashioned" winter in the first group, there would be an "old-fashioned" winter in the second. And so on, through the list. In other words, weather and climate have not changed from the time of the landing of the earliest pilgrims on the inhospitable shores of New England down to the present day.

Why the Popular Belief in Climatic Changes is Untrustworthy. Why is the popular belief in a change of climate so widespread and so firmly fixed, when instrumental records all go to show that this belief is erroneous? It is not easy to answer this question satisfactorily, but several possible explanations may be given. The trouble arises chiefly from the fact that we place absolute trust in our memories, and attempt to judge such subtle things as climatic changes on the basis of these memories, which are at best short, defective, and in the highest degree untrustworthy. We are likely to exaggerate past events; to remember a few exceptional seasons which, for one reason or another, made a deep impression on us, and we thus very much overrate some special event. To make use of an illustration given by another, individual severe winters which, as they occur,

may be some years apart, seem, when looked back upon from a distance of several years later, to have been close together. It is much as in the case of the telegraph poles along a railroad track. When we are near the individual poles, they seem fairly far apart, but when we look down the track, the poles seem to stand close together. The difference in the impressions made upon youthful and adult minds may account for part of this misconception regarding changes of climate. To a youthful mind a heavy snowstorm is a memorable thing. It makes a deep impression, which lasts long and which, in later years, when snowstorms are just as heavy, seems to dwarf the recent storms in comparison with the older. The same is true regarding heavy rains, or floods, or droughts.

Changes of residence may account for some of the prevailing ideas about climate. One who was brought up as a child in the country, where snow drifts deep and where roads are not quickly broken out, and who later removes to a city, where the temperatures are slightly higher, where the houses are warmer, and where the snow is quickly removed from the streets, naturally thinks that the winters are milder and less snowy than when he was a boy. Similarly, a change of residence from a hill to a valley, or *vice versa,* or from the coast to the interior, may easily give the impression of a changing climate. Even in cases where individuals have kept a record of thermometer readings during a long series of years,

and are sure that the temperatures are not as low or as high as they used to be, or who are convinced that the rainfall is lighter or heavier than it was some years before, the chances are that the location of the thermometer, or the exposure of the rain gauge, has been changed sufficiently to account for any observed difference in the readings.

Value of Evidence Concerning Changes of Climate. The body of facts which has been adduced as evidence of progressive changes of climate within historical times is not yet sufficiently large and complete to warrant any general correlation and study of these facts as a whole, especially from the point of view of possible causation. But there are certain considerations which should be borne in mind in dealing with this evidence, certain corrections, so to speak, which should be made for possible controls other than climatic, before conclusions are reached in favour of climatic changes. In the first place, it has been noted above that changes in the distribution of certain fruits and cereals, and in the dates of the harvest, have often been accepted as undoubted evidence of changes in climate. Such a conclusion is by no means inevitable, for it can easily be shown that many changes in the districts of cultivation of various crops naturally result from the fact that grapes, or corn, or olives, are in time found to be more profitably grown, or more easily prepared for market in another locality. Thus the area covered by vineyards in northern Europe has been very much restricted in the

last few hundred years, because grapes can be raised better and cheaper farther south. Cultivation in one district is abandoned when it is more profitable to import the product from another. It is easy, but not right, to conclude that the climate of the districts first used has changed. Wheat was formerly more generally cultivated far north in the British Isles than is the case at present, because it was profitable. Later, after a readjustment of the taxes on breadstuffs, it was no longer profitable to grow cereals in that region, and the area thus cultivated diminished. Changes in the facility, or in the cost, of importation of certain articles of food from a distance are speedily followed by changes in the districts over which these same crops are grown. Similarly, the introduction of some new plant, better suited to the local soil and climate, will result in the replacement of the older product by the newer. In France, Angot has made a careful compilation of the dates of the vintage from the fourteenth century down to the present time, and finds no support for the view so commonly held there that the climate has changed for the worse. The dates of the vintage do, however, indicate some oscillation of the climatic elements. In the period 1775–1875, the average date of the grape harvest in Aubonne was about ten days earlier than during the preceding century, but three days later than during the second century preceding. At the present time, the average date of the grape harvest in Aubonne is exactly the same as at the close of the sixteenth century. After

a careful study of the conditions of the date tree, from the fourth century B. C., Eginitis concludes that the climate of the eastern portion of the Mediterranean basin has not changed appreciably during twenty-three centuries. In China, a comparison of the ancient and present-day conditions of cultivation, of silk production, and of bird migrations, has led Biot to a similar conclusion. In some cases, the reported cultivation of cereals, or other soil products, in certain climates at present unfavourable has been shown to be purely a myth; as in the case of a supposed extended cereal cultivation in Iceland in former times.

Secondly, a good many of the reports by explorers from little-known regions are contradictory. Thus Lake Aral, which was diminishing in area for many years, is recently reported by Berg as increasing. Lake Balkash, which was rapidly drying up, has also begun to fill again. Partly submerged trees are noted as having been seen by Berg, who in June, 1902, found the lake waters quite fresh. As the lake has no outlet, this is an interesting fact. In Africa, Lake Victoria, which, it was generally agreed, was sinking in the period 1878–1892, has since shown a tendency to rise. Lake Rukwa, east of Tanganyika, has risen within the last few years. Reports that the Sea of Azov is drying up have been explained as due to a silting up of the lake. Lake Chad is very probably subject to oscillations, sometimes spreading beyond its usual limits as the result of several years of

heavy rainfall. Such diverse reports show the need of caution in jumping at conclusions of climatic change. An increased use of water for irrigation may cause the level of water in a lake to fall, as has been the case to some extent in Great Salt Lake. Periodic oscillations, giving higher and then lower water, do not indicate progressive change in one direction. Many writers have thus seen a law in what was really a chance coincidence. Partsch believes that the ancient settlements on the interior lakes of northern Africa show that these lakes contained no more water formerly than they do now. Some have claimed that the supposed desiccation of the climate of northern Africa resulted from deforestation, but no certain evidence exists of the presence or destruction of such forests, and if deforestation did take place, no considerable change of climate could have resulted.

Thirdly, where a progressive desiccation seems to have taken place, the question should be asked, Is less rain actually falling, or have the inhabitants less capacity, less energy, less ability, than formerly? Is the change from a once cultivated area to a barren expanse the result of decreasing rainfall, or of the emigration of the former inhabitants to other lands? The difference between a country formerly well irrigated and fertile, and a present-day, sandy, inhospitable waste may be the result of a former compulsion of the people, by a strong governing power, to till the soil and to irrigate, while now, without that com-

pulsion, no attempt is made to keep up the work. The incapacity of the present inhabitants, or of their rulers, is often responsible for effects which have been interpreted as due to climatic change. Where irrigation is now being again resorted to in parts of the districts about the Mediterranean which have been reported to be drying up, there the former fruitfulness is returning. In Asia Minor, for example, the rule of the Turk brought a change from a settled and civilised to a semi-nomadic state of society; industries died out, the land to a great extent passed out of cultivation; irrigation works were destroyed. Recently the building of railroads and of roads has been followed by a revival of industry and of agriculture, and by the reclamation of waste land. In many cases the reports of increasing dryness really concern only the decrease in the water supply from rivers and springs, and it is well known that a change in the cultivation of the soil, or in the extent of the forests, may bring about marked changes in the flow of springs and rivers without any essential change in the actual amount of rainfall. These conditions are particularly likely to occur in regions where there is no snow covering, and where the rain falls in a few months only. In Tripoli, the Vicomte de Mathuisieulx finds that the Latin texts and monuments seem to establish the fact that, so far as atmospheric conditions and soil are concerned, everything is just as it was in ancient times. The present condition of the country is ascribed to the idleness of the Arabs,

who have allowed wells to become choked and vegetation to perish. "In a country so little favoured by nature, the first requisite is a diligent and hard-working population. The Romans took several centuries to make the land productive by damming rivers and sinking wells in the *wady* beds." In an arid region, man has a hard task if he is to overcome the climatic difficulties of his situation. Irrigation; the choice of suitable crops adapted to arid conditions; steady, thoughtful work, are absolutely essential. To a large extent, an intelligent man may thus overcome many of the obstacles which nature has put in his way. On the other hand, a region of deficient rainfall, once thickly settled and prosperous, may readily become an apparently hopeless desert, even without the intervention of war and pestilence, if man allows the climate to master him.

Lastly, a region whose normal rainfall is at best barely sufficient for man's needs, may be abandoned by its inhabitants during a few years of deficient precipitation, and not again occupied even when, a few years later, normal or excessive rainfall occurs. It is a very striking fact that the districts from which comes most of the evidence of changes of climate within historical times are sub-tropical or sub-equatorial, *i. e.*, they are in just those latitudes in which a slightly greater or a slightly less migration of the rain-bringing conditions easily produces a very considerable increase or decrease in the annual rainfall.

It is apparent, on examining the evidence thus far

at hand, that the fact of permanent, progressive changes in climate during historical times has not yet been definitely established.

Periodic Oscillations of Climate: Sunspot Period. The discovery of a distinct eleven-year periodicity in the magnetic phenomena of the earth, naturally led to investigations of similar periods in meteorology. Numerous and varied studies along this line, extending back even into the seventeenth century, but beginning actively about 1870, have been and are still being prosecuted by a considerable number of persons, and the literature on the subject has assumed large proportions. The results, however, have not been satisfactory. The problem is difficult and obscure. It is natural to expect a relation of this sort, and some relation certainly exists. But the results have not come up to expectations. Fluctuations in temperature and rainfall, occurring in an eleven-year period, have been made out for certain stations, but the variations are slight, and it is not yet clear that they are sufficiently marked, uniform, and persistent over large areas to make practical application of the periodicity in forecasting possible. In some cases, the relation to sunspot periodicity is open to debate; in others, the results are contradictory.

Köppen has brought forward evidence of a sunspot period in the mean annual temperature, especially in the tropics, the maximum temperatures coming in the years of sunspot minima. The whole ampli-

tude of the variation in the mean annual temperatures, from sunspot minimum to sunspot maximum, is, however, only 1.3° in the tropics, and a little less than 1° in the extra-tropics. There are, however, long periods during which there appears to be no influence, or at least, an obscure one, and the relation before 1816 seems to have been opposite to that since then. More recently Nordmann (for the years 1870–1900) has continued Köppen's investigation, using the mean annual temperatures of certain tropical stations, and finds that the mean temperatures run parallel with the sunspot curve, but that the minimum temperatures occur with the sunspot maxima (amplitude 0.7°). This seems to contradict the fact that the sun is hotter at a time of maximum sunspots. The latter difficulty has been explained on the ground that the rainfall and cloudiness, both of which are at a maximum with the sunspot curve, lower the temperature, especially in the tropics. It is obvious that the condition of this matter is rather confusing just at the present time, and that the relation of sunspots and terrestrial temperatures is not wholly clear. The sunspots themselves are probably not the immediate or sole control. "There seems little doubt," says Sir Norman Lockyer, "that we must look to the study of the solar prominences, not only as the primary factors in the magnetic and atmospheric changes in our sun, but as the instigators of the terrestrial variations." These investigations, however interesting and important they may be to

astronomers and physical meteorologists, are really outside the field of climatology.

In 1872, Meldrum, then director of the meteorological observatory at Mauritius, first called attention to a sunspot periodicity in rainfall and in the frequency of tropical cyclones in the South Indian Ocean. The latter are most numerous in years of sunspot maxima, and decrease in frequency with the approach of sunspot minima. Poëy later found a similar relation in the case of the West Indian hurricanes. Meldrum's conclusions regarding rainfall were that, with few exceptions, there is more rain in years of sunspot maxima. This is to be taken only for *means,* and for a majority of stations, and is not to be expected at all stations, or in every period. Hill found it to be true of the Indian summer monsoon rains that there seems to be an excess in the first half of the cycle, after the sunspot maximum. The winter rains of northern India, however, show the opposite relation; the minimum following, or coinciding with, the sunspot maximum. Many studies have been made of a possible relation between rainfall and the sunspot period, but the conclusions are not very definite, are sometimes contradictory, and do not yet warrant any general, practical application for purposes of forecasting the wet or dry character of a coming year. Particular attention has been paid to the sunspot cycle of rainfall in India, because of the close relation between famines and the summer monsoon rainfall in that country. In 1889, Blanford

admitted that the rainfall of India as a whole did not give evidence of the sunspot cycle in the records of the twenty-two years preceding. More recently, the Lockyers have studied the variations of rainfall in the region surrounding the Indian Ocean in relation to solar changes in temperature. They find that India has two pulses of rainfall, one near the maximum and the other near the minimum of the sunspot period. The famines of the last fifty years have occurred in the intervals between these two pulses, and these writers believe that if as much had been known in 1836 as is now known, the probability of famines at all the subsequent dates might have been foreseen.

Relations between the sunspot period and various meteorological phenomena other than temperature, rainfall, and tropical cyclones have been made the subject of numerous investigations, but, on the whole, the results are still too uncertain to be of any but a theoretical value. Some promising conclusions seem, however, to have been reached in regard to pressure variations, and their control over other climatic elements.

Brückner's Thirty-five-Year Cycle. Of more importance than the results thus far reached for the sunspot period are those which clearly establish a somewhat longer period of slight fluctuations or oscillations of climate, known as the Brückner cycle, after Professor Brückner, of Berne, who has made a careful investigation of the whole subject of climatic changes and finds evidence of a thirty-five-year

periodicity in temperature and rainfall. Brückner began with the long-period oscillations in the level of the Caspian Sea. He then investigated the levels of the rivers flowing into the Caspian, and next the dates of the opening and closing of the rivers of the Russian Empire, and finally extended his study over a considerable part of the world, including data concerning mean temperatures, rainfall, grape harvest, severe winters, and the like. The dates of opening and closing of Russian rivers go back in one case to 1559; the dates of vintage to the end of the fourteenth century, and the records of severe winters to about 1000 A.D. In a cycle whose average length is thirty-five years there comes a series of years which are somewhat cooler and also more rainy, and then a series of years which are somewhat warmer and drier. Brückner has found that the price of grain averages 13 per cent. higher in the wetter lustrum than in the drier. This thirty-five-year period is not to be thought of as being a perfectly systematic recurrence, in exactly that term of years. The interval in some cases is twenty years; in others, it is fifty. The *average* interval between two cool and moist, or warm and dry periods, is about thirty-five years. Moreover, not only the intervals, but the intensities of the individual periods vary. The mean amplitude of the temperature fluctuation, based on large numbers of data, is a little less than 2°, which makes it greater than that obtained by Köppen for the sunspot period, and it is natural to expect it at a maximum in

continental climates. The fluctuations in rainfall, also, are more marked in interiors than on coasts. The general mean amplitude is 12 per cent., or, excluding exceptional districts, 24 per cent. In western Siberia more than twice as much rain may fall in wet as in dry periods. Regions whose normal rainfall is small are thus most affected. In years of minimum precipitation they may become uninhabitable, and the population may be forced to move away, perhaps never returning, and allowing towns and irrigating works to fall to decay. Slight fluctuations in rainfall are most critical in regions having a normal precipitation barely sufficient for agriculture. The extent of land cultivated, and the returns of agriculture here fluctuate directly with the temporary increase or decrease of rainfall. A supplementary study of the newer rainfall observations for Russia and for the United States, as well as for certain stations in central Europe and eastern Siberia, has given Brückner satisfactory confirmation of his earlier conclusions in the fact that he finds a decrease of rainfall over these districts as a whole, beginning about the middle of the decade 1880–90. The time of the "boom" in western Kansas and Nebraska, and in eastern Colorado, in the decade 1880–90, followed one of Brückner's wet periods, and the collapse of the "boom" came when the drier period advanced. Farmers who went out onto the high plains in the years of slightly greater rainfall preceding the boom, and who lost all their capital, and more too, in the

vain attempt to raise their grain in the years which followed, could with difficulty be convinced that the climate of the plains had not permanently changed for the worse. The impression left upon their minds, and upon the mind of anyone who saw the country later, was one of decreasing rainfall, unsuccessful agriculture, and financial ruin. Within more recent years, in this same region of Kansas, with a somewhat increased rainfall during a wetter cycle, but without any permanent change to a wetter climate, the intelligent choice of cereals better adapted to the soil and climate, and the rational use of the available water supply, have wrought a wonderful change in the aspect and economic value of the state,

The following table shows the characters and dates of Brückner's periods:

Warm	1746–1755	1791–1805	1821–1835	1851–1870	
Dry	1756–1770	1781–1805	1826–1840	1856–1870	
Cold	1731–1745	1756–1790	1806–1820	1836–1850	1871–1885
Wet	1736–1755	1771–1780	1806–1825	1841–1855	1871–1885

Interesting confirmation of Brückner's thirty-five-year period has been found by Richter in the variations of the Swiss glaciers, but as these glaciers differ in length, they do not all advance and retreat at the same time. The advance is seen during the cold and damp periods. Supan has pointed out that the Brückner periods appear to hold good in the south polar regions. And Hann's study of the monthly and annual means of rainfall at Padua (1725–1900), Klagenfurt (1813–1900), and Milan (1764–1900)

brings to light an alternation of wet and dry periods in harmony with the thirty-five-year cycle. It should be noted that Brückner has found certain districts in which the phases and epochs of the climatic cycle are exactly reversed. These exceptional districts are almost altogether limited to marine climates. There is thus a sort of compensation between oceans and continents. The rainier periods on the continents are accompanied by relatively low pressures, while the pressures are high and the period dry over the oceans, and *vice versa*. The cold and rainy periods are also marked by a decrease in all pressure differences. It is obvious that changes in the general distribution of atmospheric pressures over extended areas, of the great centres of high and low pressure, are closely associated with fluctuations in temperature and rainfall. An oscillation of a few hundred miles one way or another may mean the difference between drought and plentiful rainfall over extended areas. These changes in pressure distribution must in some way be associated with changes in the general circulation of the atmosphere, and these again must depend upon some external controlling cause, or causes. W. J. S. Lockyer has called attention to the fact that there seems to be a periodicity of about thirty-five years in solar activity, and that this corresponds with the Brückner period. This longer cycle, underlying the sunspot period, alters the time of occurrence of the sunspot maxima in relation to the preceding sunspot minima. He makes out

three periods in solar activity, of between three and four years, about eleven, and about thirty-five years, respectively. These are related as 1:3:9.

It is clear that the existence of a thirty-five-year period will account for many of the views that have been advanced in favour of a *progressive* change of climate. A succession of a few years wetter or drier than the normal is likely to lead to the conclusion that the change is permanent. Accurate observations, extending over as many years as possible, and discussed without prejudice, are necessary before any conclusions are drawn. Observations for one station during the wetter part of a cycle should not be compared with observations for another station during the drier part of the same, or of another cycle.

Climatic Cycles of Longer Period. There are evidences of longer climatic cycles than eleven or thirty-five years. Brückner calls attention to the fact that sometimes two of his periods seem to merge into one. Richter shows much the same thing for the Alpine glaciers. James Geikie, in Scotland, has brought forward evidence of several climatic changes in post-glacial times. Blytt, in Norway and Sweden, finds some botanical evidence of four great climatic waves since the last glacial period. Brögger estimates that a mean annual temperature between 3° and 4° higher than the present was found in the Christiana Fjord in post-glacial time. Lorié, in Holland, finds confirmation of Blytt's views. Gradmann, on botanical evidence, believes in a warmer climate in

central Europe after the last ice age, and then a cooler one. Clough concludes that a three-hundred-year cycle exists in solar and terrestrial phenomena, the thirty-six-year cycle being, as it were, superimposed upon the longer one. Kingsmill reports a periodicity of three hundred years in droughts and famines in northern China. And so on. As yet, nothing sufficiently definite to warrant discussion here has been brought forward.

Geological Changes in Climate. Changes of climate in the geological past are known with absolute certainty to have taken place; periods of glacial invasions, as well as periods of more genial conditions. The evidence and the causes of these changes have been discussed and re-discussed, by writers almost without number, and from all points of view. Changes in the intensity of insolation; in the sun itself; in the conditions of the earth's atmosphere; in the astronomical relations of earth and sun; in the distribution of land and water; in the position of the earth's axis; in the altitude of the land; in the presence of volcanic dust—changes now in cosmic, now in terrestrial conditions—have been suggested, combatted, put forward again. None of these hypotheses has prevailed in preference to others. No actual proof of the correctness of this or that theory has been brought forward. No general agreement has been reached. Under these conditions, and in view of the fact that practical climatology is concerned with climatic changes, not of the geological

past but of the historical present, this portion of our subject may be dismissed with this brief mention.

Conclusion. There is a widespread popular belief in permanent, progressive changes of climate during a generation or two. This belief is not supported by the facts of meteorological record. Abundant evidence has been adduced in favour of secular changes of climate in historical times. Much of this is untrustworthy, contradictory, and has been interpreted without sufficient regard to possible controls other than climatic change. Without denying the possibility, or even the probability, of the establishment of the fact of secular changes, there is as yet no sufficient warrant for believing in considerable *permanent changes over large areas.* Dufour, after a thorough study of all available evidence, has concluded that a change of climate has not been proved. There are periodic oscillations of slight amount. An eleven-year period has been made out, with more or less certainty, for some of the meteorological elements, but it has been of no practical importance as yet. A thirty-five-year period is less uncertain, but is nevertheless of considerable irregularity, and can not as yet be practically applied in forecasting. Longer periods are suggested, but not surely established. As to causes, variations in solar activity are naturally receiving attention, and the results thus far are promising. But climate is a great complex, and complete and satisfactory explanations of all the facts will be difficult, perhaps impossible, to reach. At

present, indeed, the facts which call for explanation are still in most cases but poorly determined, and the processes at work are insufficiently understood. Climate is not absolutely a constant. The pendulum swings to the right, and to the left. And its swing is as far to the right as to the left. Each generation lives through a part of one, or two, or even three, oscillations. A snap-shot view of these oscillations makes them seem permanent. As Supan has well said, it was formerly believed that climate changes locally, but progressively and permanently. It is now believed that oscillations of climate are limited in time, but occur over wide areas. Finally, it is clear that man, whether by reforestation or deforestation, by flooding a desert or by draining a swamp, can produce no important or extended modifications of natural climate. This is governed by factors beyond human control.

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